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Reducing Travel by Design

A Micro Analysis of New Household Location and the Commute to Work in Surrey

PhD Final Thesis

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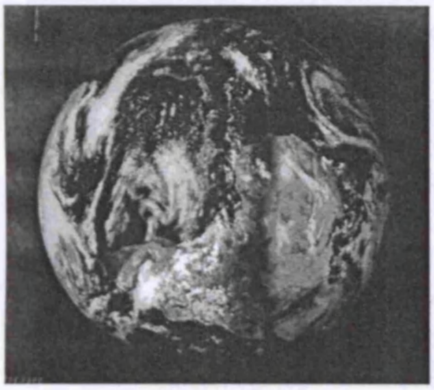
Thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at University College London.



"The rise of environmental consciousness is one of the major cultural and political transformations of the past three decades (Capra, 1995) *...yet at the same time resource consumption and environmental degradation continues. [As yet] we are only aware of the process by which our species is committing environmental suicide."*

(Castells, 1999, in The Castells Reader, Ed. Susser, 2002, p.376)

Abstract

Traffic volumes (and hence energy consumption) from the transport sector continue to rise, yet the potential fundamental role of urban planning in helping to reduce transport energy consumption remains to be poorly understood and hugely underplayed. Current urban planning practice, particularly in suburban areas, tends to increase traffic volumes by dispersing activities and hence facilitates private car travel rather than travel by public transport, walking or cycling. Public transport orientated development as an evolving practice tends to be focused very much on urban areas.

This thesis seeks to understand the logic behind travel and suggests that urban planning can be applied more fully, at the strategic and local levels, to reduce energy consumption in car use (at least in the journey to work). The detailed analysis assesses the extent to which the design of the urban environment affects travel behaviour. The research hypothesis is that: "Journey to work travel behaviour generated by new residential development is dependent on a number of land use and socio-economic variables. The strength, significance and range of interaction vary spatially and over time." Within the analysis, the journey to work is used as the dependent variable, and is measured in terms of journey length and time, mode share and [composite] energy consumption. The independent variables considered include:

- Land use: resident population density, resident employment density, workplace population density, workplace employment density, resident population size, workplace population size, distance from urban centres and strategic transport networks, jobs-housing balance, resident classification (relative to the urban area), type of journey to work, neighbourhood streetscape design, public transport accessibility, and resident location (relative to the green belt).
- Socio-economic: household tenure, house type, house size, number of children, car availability, company car ownership, household income, house value, respondent sex, respondent age, marital status, occupation, qualification, attitude to travel, attitude to home and home location, reason for moving home and choosing new home location, relative levels of mobility, and dual income households.

The methodological approach is to systematically examine the study hypothesis and a series of related research questions using data from the county of Surrey, UK. The empirical analysis is based on two new household occupier surveys carried out in 1998 and 2001, together with additional, complementary data taken from local authority datasets and the Census 2001. The thesis's particular originality is in providing:

- An examination of the complexity of the land use and transport interaction field, using energy consumption as the dependent variable; and an estimation of the strength and significance of a wide range of land use and socio-economic variables - both previously researched and under researched variables;
- A segmentation of respondents into different groups, such as stayers, inmovers and outmovers, showing the different manifestation of the land use and transport relationship for different groups within society;
- A systematic tracking of the impact of time on the land use and transport relationship, with temporality and adaptation (including "co-location" effects) noted as critical features in travel behaviour, with the analysis controlling for potential attrition factors;
- Analysis of a seldom-studied London fringe/suburban county such as Surrey - much previous work is concentrated on the city or other urban areas.

The key findings and recommendations are that each land use, socio-economic and attitudinal variable, when considered on its own or even in small groupings, offers limited explanatory power in explaining travel behaviour. When a number of variables are brought together, including some variables not usually considered in the literature, the explanatory power of the modelling begins to work. Linear regression analysis shows that the land use and socio-economic variables, when considered together, explain 60% of the variation in energy consumption in 1998 and 54% in 2001; and [for the stayers data only] explain 65% of the variation in energy consumption in 1998 and 54% in 2001. Land use variables by themselves contribute approximately 10% of the variation in transport energy contribution; hence a major part of the logic behind travel.

In terms of temporal change from 1998-2001, although aggregate distance co-location might occur, aggregate energy consumption is likely to increase due to increased car dependency. Also, focusing on the aggregate trends also hides several detailed kurtosis effects: households located at higher densities, closer to major strategic centres, in areas with good public transport accessibility and strong jobs-housing balance are all likely to reduce their commuting travel distance. Other groups are likely to increase their composite transport energy consumption, for example, the higher income cohorts.

Integration thus requires action across a wide range of fields. New households, for example, should be located in a coordinated manner in relation to the density of development, settlement size, distance from urban centres and transport networks, jobs and housing balance, local neighbourhood design, public transport accessibility and green belt designation. Ad-hoc, cumulative "pepperpotting" of new housing development no longer remains an option. Through such context-sensitive "smart growth" strategies, reduced transport energy consumption can be enabled; and transport sustainability achieved in the location of major new development. Urban planning therefore becomes a *critical tool* in efforts to reduce journey to work energy consumption.

Acknowledgements

P.G. Wodehouse, in the dedication to the *Heart of a Goof* (1926), stated "*To my daughter Leonara without whose never-failing sympathy and encouragement this book would have been finished in half the time.*"

Luckily Martha only arrived post-Viva, during the thesis mods. Otherwise the whole process may have taken even longer! A good number of people have been involved in the development of the analysis used in the thesis. Without them it would not have been possible. So huge thanks to all.

- Number one is, as ever, to Helen: thanks for the help and the patience, and generally for letting me "disappear" whilst developing and writing the thesis. I couldn't have done it without you. LOVE and huge thanks again.

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And lastly, for helping with all those hours spent alone at the keyboard, at times patiently, and at others not so patiently - Neil Young, Radiohead, Bob Dylan, Ride and many, many others - you write some great tunes; let's hope my work is half as good as your output.

Thanks again, enjoy the read!

Rob

Ealing, 2007.

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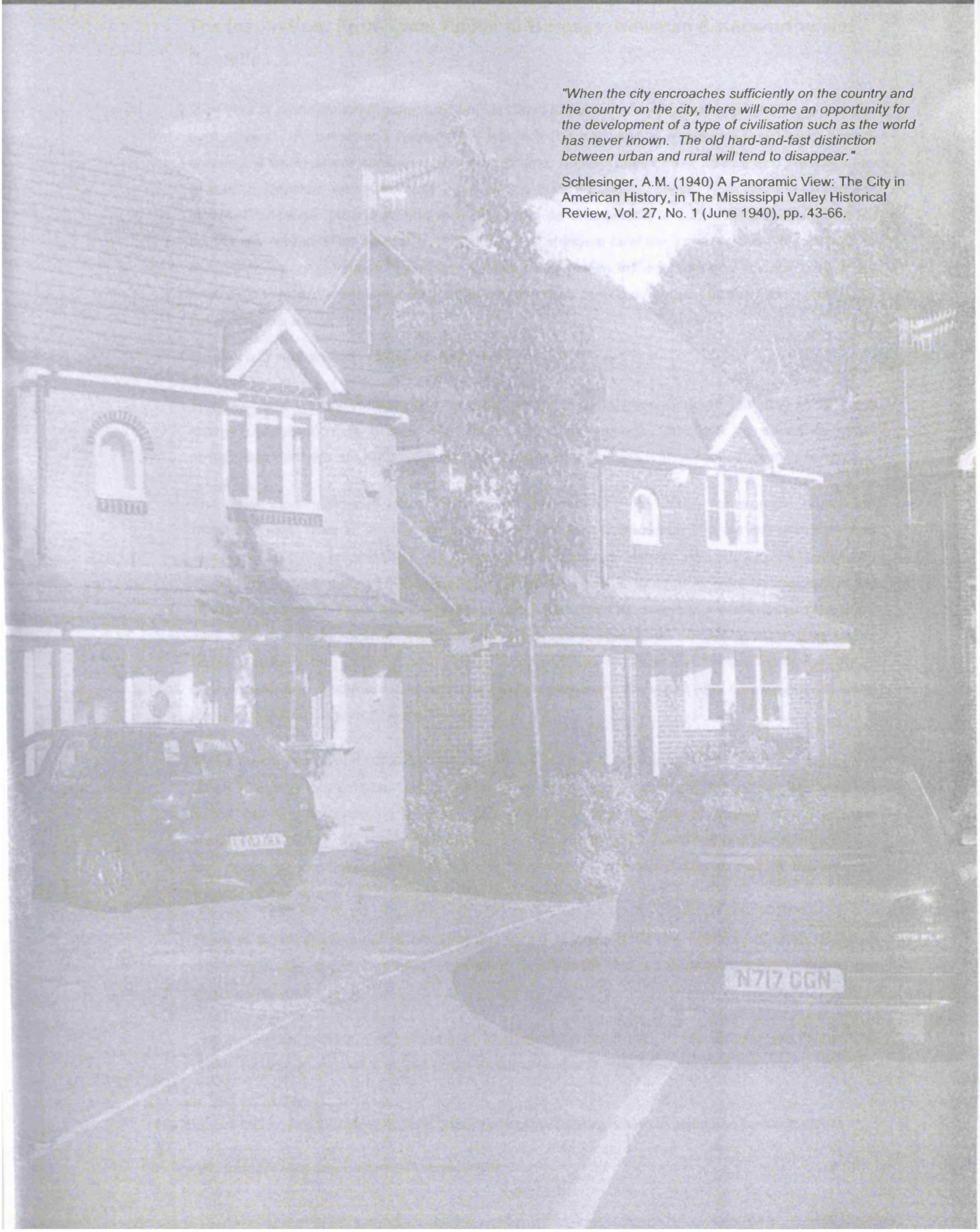
All photographs by Robin Hickman unless stated.

01 Introduction

"When the city encroaches sufficiently on the country and the country on the city, there will come an opportunity for the development of a type of civilisation such as the world has never known. The old hard-and-fast distinction between urban and rural will tend to disappear."

Schlesinger, A.M. (1940) A Panoramic View: The City in American History, in The Mississippi Valley Historical Review, Vol. 27, No. 1 (June 1940), pp. 43-66.



1. Introduction

1.1 The Inspiration: From Çatal Hüyük to Burgess, Newman & Kenworthy and Castells

"The idea of planners turning our lives upside down in pursuit of a single-minded goal is as horrible as it is alien. Newman and Kenworthy's world is the Kafkaesque nightmare that Hayek always dreaded, a world where consumers have no choice, relative prices have no role and planners are tyrants ... Newman and Kenworthy have written a very troubling paper. Their distortions are not innocent, because the uninformed may use them as ammunition to support expensive plans for central city revitalisation and rail transit projects or stringent land use controls in a futile attempt to enforce urban compactness ... perhaps Newman and Kenworthy would be well advised to seek out another planet, preferably unpopulated, where they can build their compact cities from scratch with solar powered transit."

Gordon and Richardson (1989), pp. 342-345.

Transport and energy consumption, and the potential contribution of urban planning in reducing energy consumption, is a topic that is becoming increasingly important as efforts to attain sustainable lifestyles are progressively more sought after, yet prove intractably difficult to achieve.

The varied development of urban areas is well documented. Soja (2000), for example, details the origins of urban form all the way back to the very earliest settlements. The earliest developments suggest that 'proto-urbanisation' was found at sites such as Jericho, Abu Hureya, Mureybat and Çatal Hüyük more than 10,000 years ago. 'True city form' is thought to have developed on the alluvial plains of the Tigris and Euphrates, in the area known as Sumeria, sometime between 4000 and 3000 BC. Since these times, urban areas have developed at an increasing rate. Some have been planned, the majority not. Energy consumption, of finite resources, continues at an exponential rate. There are now well over 6 billion persons in the world[1]; the vast majority of these travel and consume energy in their travel.

This thesis takes this urban history and growth as its context, and draws on the classical tradition of urban planning intervention, both in terms of research and practice. Its theoretical framework is based on the long-running debates concerning the improvement of quality of life in, and sustainability of, regions, cities and towns. It covers the disciplines of urban and transport planning and seeks to understand whether we can intervene in urban planning to reduce the adverse impacts of travel, and particularly that of energy consumption.

There is a rich tradition of research in attempting to understand the workings of cities: Burgess (1925) provides a real highlight, attempting to articulate that an underlying logic exists to the structure of cities.

Two quotations provide much of the early inspiration for the thesis. Firstly, Gordon and Richardson (1989, as above) famously criticised the well-known thesis from Newman and Kenworthy (1989a) -

[1] The "Day of 6 Billion" was 12th October 1999. There are now approaching 6.6 billion persons in the world (2007).

that urban density and energy consumption in transport might be related - and the added [attractive] implication that higher density, compact cities might reduce travel and energy consumption. Over 25 years of research has passed and many of the findings, although interesting and valuable in their own right, have tended to be inconclusive. There is still little consensus as to the relationships between land use and travel, and less still as to how (or whether) land use can (or should) be structured to reduce travel. The potential for urban planning as a key tool in achieving reduced energy consumption in travel remains unquantified and, as a result, hugely under-estimated.

The growing interest in sustainability in transport and urban living, and the growing imperative of global warming, however make this area of research very topical. This provides a renewed focus for researchers in attempting to understand the logic behind land use, the relationships between land use and travel, and the ultimate goal here: whether land use can be designed to help achieve sustainability.

There is also an added dimension to this thesis: how temporal changes are related to spatial change. The second key inspiration is thus from Castells (1996, p.429):

"*We are embodied time, and so are our societies, made out of history.*"

The broad topics of research are therefore of land use and travel; and of change over time. These topics are considered in relation to new housing location and travel behaviour.

1.2 The Context: Undertanding the Logic Behind [Integrated] Urban and Transport Planning

So to the broader context. To pick out key literature references[2] is difficult because of the breadth and depth of the field. One-line summaries of years and years of research effort can be misleading. However, contextual references are important to a thesis such as this: and a [very] potted and selective history follows.

Sitte (in *The Art of Building Cities*, 1889) effectively launched the modern study of urban design with detailed studies of the built environment around Europe. Howard (*Garden Cities of To-morrow*, 1898) is critically important in developing plans for self-contained communities outside crowded central cities, integrating nature into cities, green belts, zoning of uses, and laid the foundations for the profession of modern city planning. Geddes (*Cities in Evolution*, 1915) developed urban theory, notably in terms of understanding regionalism and describing the growth of urban agglomerations. Burgess (*The Growth of the City*, 1925), as previously noted, develops the notion of a logic behind land use. Lynch (*The Image of the City*, 1960), as an important parallel, seeks to understand how people perceive city form. Jacobs (*The Death and Life of Great American Cities*, 1961) argues for city living and urbanism, at a time when inner-city communities were increasingly being abandoned. Hall (*Cities of Tomorrow*, 1988a and *Cities in Civilisation*, 1998) provides an understanding of the historical context for contemporary urban planning theory, and Soja (*Postmetropolis*, 2000) retreats to the origins of land use. Digital futures are prophesised by

Negroponte (*Being Digital*, 1995); and Castells (*The Information Age: Economy, Society and Culture*, 1996/1997/1998). Castells in particular has produced a remarkable breadth of thought on contemporary urban society, dating from the early 1970s (see *The Urban Question*, 1972 and later publications). Lefebvre (*The Right to the City*, 1967, and later publications) has similarly philosophised on urban life.

The transportation planning field has evolved in parallel to that of urban planning over the last 40 years, yet arguably is not as well developed in theoretical terms. Banister (*Transport Policy and the Environment*, 1998a; and *Transport Planning*, 2002) gives a thorough overview. Developing from systems analysis in the 1960s, the Chicago Area Transportation Study (1960) provides one of the early defining moments. Thompson (*Modern Transport Economics*, 1974) summarises the basic transport planning model: expected vehicle and passenger volumes are estimated in the main travel corridors, increases in road and public transport capacities are proposed to accommodate the forecast increases. This basic model - catering for projected demand - has run throughout the history of modern transport planning practice. It is still the basis for much of consultancy practice today.

The Buchanan Report (*Traffic in Towns*, 1963) is frequently perceived as being seminal, with two distinct contributions: a realisation that large increases in road capacity tended to exacerbate problems of traffic congestion, rather than solving them; and the notion of significant environmental disbenefits being linked to traffic.

The debate has moved on somewhat over the years, but with frequent time lags between agreed consensus and implementation. The Smeed Report (1964) provides the classic example; introducing the concept of charging for travel; and only recently realised in Singapore, Oslo, Trondheim, Bergen and London.

Of huge importance has been the strong movement against proposed large-scale road building programmes and the focus on transport planning as a tool in designing quality urban spaces. Appleyard (*Liveable Streets*, 1981); Roberts (*Quality Streets*, 1988); Pharoah (*Less Traffic, Better Towns*, 1992); Hass-Klau (*Civilised Streets*, 1992); Calthorpe (*The Next American Metropolis*, 1993); Gehl (*Life Between Buildings*, 1987); Hillier (*Space is the Machine*, 1996); and Hillman, Adams and Whitelegg (*One False Move*, 1993) providing some of the real highlights here. Important contributions are also made in terms of the "new realism" in transport (Goodwin, Hallet, Kenny and Stokes, 1991); induced traffic and traffic degeneration (Cairns, Hass-Klau and Goodwin, 1998); "smarter choices" (Cairns et al, 2004); and the emerging transport and global warming field (Hickman and Banister, 2006).

We are now beginning to appreciate that demand-led transport planning is not appropriate to much of modern day life. Traffic demand management - with a focus on transport as a tool in improving quality of life and sustainability - is increasingly coming into vogue.

Much of the better thinking in the literature is multi-disciplinary in nature - covering urban planning, transport planning and urban design - and wider considerations such as social, behavioural,

[2] See LeGates and Stout (*The City Reader*, 2000) for an excellent introduction to the urban studies literature field, as well as other publications in the City Reader series.

political, historic and economic issues. Sustainability runs as a theme through much of this work, particularly in the later publications, with a focus on addressing economic, environmental and social (and sometimes institutional) objectives. These issues are considered in more detail - as part of a more thorough literature review - in Chapter 2. The Brundtland Report (*Our Common Future*, 1987), of course, is the benchmark here, together with a lengthy history of global climate change research, including major conventions such as Rio de Janeiro in 1992, Kyoto in 1997 and Johannesburg in 2002, and most recently Montreal (2005).

Integrated urban and transport planning has been the focus of much recent discussion, with transportation problems entering discussions concerning 'efficient' urban form. Importantly, air pollution, energy consumption and traffic congestion costs continue to rise in most towns and cities, and getting people to reduce the impact of their car dependent lifestyles remains inextricably difficult.

This thesis is focused on these particular problems. With the multi-disciplinary literature fields of urban and transport planning as context, the analysis considers the scope for using land use planning in reducing travel by the private car. The questions underlying the study are as follows:

- To what extent does the built environment affect how often and how far people drive the car or use the bus or train? How do socio-economic circumstances affect travel behaviour; and how do they interrelate with land use factors?

- Does the land use and transport interaction relationship change by location and over time? Do individuals modify their travel behaviour over time? Does co-location of residence and workplace occur?

- And finally, can land use policy and planning be strategically and locally applied to reduce car use?

A rapidly expanding literature field is focused on investigating the potential for land use planning and urban form to influence travel behaviour. An important dimension is that of land use change over time: land use change is typically in the region of 1-2% p.a., which can be argued to be of limited significance. However this change takes on greater importance incrementally over time. Also, locally, major developments, such as new housing or employment developments, or a new health or leisure centre, have a disproportionately large impact on travel behaviour patterns when built.

A number of topic areas have received considerable coverage in the literature, such as: the influence of population size, density, the provision and mix of local facilities, local urban form, the location of development, balance of jobs and housing and also wider socio-economic variables, such as income and household composition.

Hugely conflicting messages however arise from the research. Debate remains as to the relative contribution of each variable in terms of influencing travel behaviour and there remains considerable disagreement. Attempts to categorise particular contributions in the literature field are fraught with difficulties, notably those of over-simplification and generalisation. However

Schwanen et al (2001) have identified two broad camps; these are detailed – and slightly amended – as below:

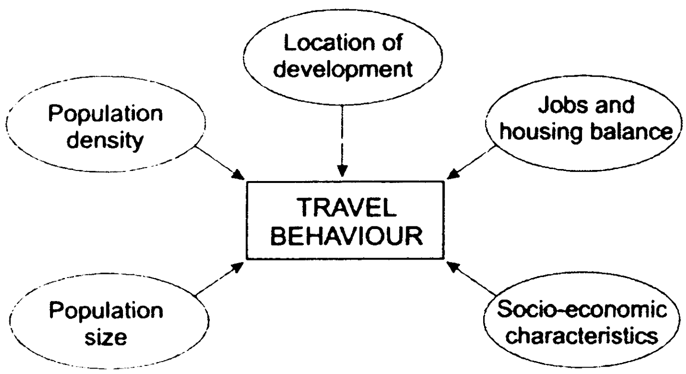
- The interventionists: who assert that land use can and does impact on travel behaviour, and, critically, can be used to design more sustainable towns and cities (work drawing on empirical evidence mostly from compact city examples in Europe and Australia, e.g. Newman and Kenworthy, 1989 and 1999; Cervero, 1989; Curtis and Headicar, 1994; and Ewing 1997).

- The sceptics: who query the usefulness of planning interventions, and sometimes further, that the efficiency of 'invisible hand' market mechanisms leads naturally to a 'co-location' of residential and employment locations. They believe that adjustments occur over time – unrelated to planning interventions - which bring workplaces and homes closer together and reduce commuting costs and distances (much of this work is based on research from suburban Los Angeles, e.g. Gordon and Richardson, 1997; and Levinson and Kumar, 1994).

The latter grouping broadly postulate that suburbanisation trends do not lead to the expected increases in traffic volumes (other variables, such as socio-economic factors, are perceived as more important) and there is little need to attempt to intervene and influence patterns of travel through modifying land uses. Breheny (1992) has developed parallel views in the UK, also stressing that the trend towards counter-urbanisation may be too great to reverse by planning interventions. A further consideration is the role of travel cost and pricing. Breheny, for example, argues that changes here can play a more important role in influencing travel behaviour than attempts to change land use planning. Echenique (2001) has argued along similar lines.

Increasingly researchers are looking in more detail at the land use and transport relationships, with a real focus on what actually is happening on the ground in terms of travel behaviour. Figure 1.1 highlights the main land use and socio-economic variables which are most often noted as influencing travel behaviour.

Figure 1.1: *Previously Researched Land Use Impacts on Travel Behaviour*



1.3 Deconstructing the Literature Field: Key Issues and Knowledge Gaps

In addition to the different nuances in argument and interpretation amongst the literature, and despite – or possibly because of - the large amount of research carried out in the land use and transport interaction field, there still remains a large number of remaining research questions. The key debates within the literature evolve around whether and to what extent travel behaviour is associated with land use and socio-economic variables.

Table 1.1 highlights a number of these debates, first by examining the existing contradictory knowledge and then by highlighting a number of the under researched areas. Research findings from the literature field are organised by topic and author.

Table 1.1: *The Knowledge Gaps*

Existing Knowledge

Resident Population Density: dispute as to whether increasing densities impacts on modal choice, travel distance and energy consumption. Various thoughts as to optimum urban form in reducing car travel; ranging from compact cities to 'decentralised concentration' and even low density suburban spread.

- Increasing densities reduces energy consumption by transport (Newman and Kenworthy, 1989a).
- There is no clear relationship between the proportion of car trips and population density in the USA (Gordon et al, 1989a).
- Having more people close to their jobs will reduce vehicle miles travelled, freeway traffic and tailpipe emissions (Cervero, 1996a).
- As densities increase, modal split moves towards greater use of rail and bus (Wood, 1994).
- Compact cities may not necessarily be the answer to reducing energy consumption, due to effects of congestion, also decentralisation may reduce trip length (Breheny, 1995a and Gordon & Richardson, 1996).
- 'Decentralised concentration' is the most efficient urban form in reducing car travel (Jenks et al, 1997).
- Density is the most important physical variable in determining transport energy consumption (Banister et al, 1997).
- Higher densities may provide a necessary, but not sufficient condition for less travel (Owens, 1998).
- As people move from big dense cities to small less dense towns they travel more by car, but the distances may be shorter (Hall, in Banister, 1998a).

Resident Population Size: dispute as to whether population size impacts on modal choice, travel distance and energy consumption.

- No correlation between urban population size and modal choice in the USA (Gordon et al, 1989a).
- The largest settlements (>250,000 population) display lower travel distances and less by car (ECOTEC, 1993).
- The most energy efficient settlement in terms of transport is one with a resident population size of 25-100k or 250k plus (Williams, 1998).
- The search for the ultimate sustainable urban form perhaps now needs to be reorientated to the search for a number of sustainable urban forms which respond to a variety of existing settlement patterns and contexts (Jenks et al, 1996)

Provision and Mix of Land Uses: dispute as to whether jobs and housing balance impacts on modal choice, travel distance and energy consumption.

- Mixing of uses is not as important as density in influencing travel demand (Owens, 1986).
- Communities with approximate jobs-housing balance see a majority of residents working in their home community (Cervero, 1989a).
- Diversity of services and facilities in close proximity reduces distance travelled, alters modal split and people are prepared to travel further for higher order services and facilities (Banister, 1996).
- Much research advocates 'contained', compact, urban layouts with a mix of uses in close proximity, i.e. a move away from functional land use zoning (Williams, 2005)

Location: dispute as to impact of location – in terms of distance from urban centre and strategic transport network - on modal choice, travel distance and energy consumption.

- Location of new housing development outside existing urban areas, or close to strategic transport network, or as free-standing development increases travel and influences mode split (Headicar and Curtis, 1994 & 1998).
- Location is an important determinant of energy consumption and car dependency (Banister, 1997a).
- Development close to existing urban areas reduces self-containment and access to non-car owners (Headicar, 1997).
- Deconcentration of urban land use to suburban locations and new towns almost certainly promotes the use of the private car for all purposes and leads to less use of public transport as well as cycling and walking. Distance to work however does not necessarily increase (Schwanen et al, 2001)

Socio-Economic: dispute as to impact of personal and household characteristics on modal choice, travel distance and energy consumption. Also as to whether personal and household characteristics are more important determinants of travel than land use characteristics.

- Trip frequency increases with household size, income and car ownership (Hanson, 1982)
- Travel distance, proportion of car journeys and transport energy consumption increases with car ownership (Naess, 1996).
- Attitude to travel is more strongly associated with travel behaviour than land use characteristics (Kitamura et al, 1997).

Under Researched Areas

Temporal Dimension

- Temporal effect: some anecdotal evidence of the 'co-location' of households and employment over time in California, USA (Gordon & Richardson, 1989a). But, few attempts to systematically track impact of time on travel behaviour.

Further Land Use Variables

- Urban design quality: some anecdotal evidence in the USA (Kulash, 1990) showing the differential impact of new urbanist versus cul-de-sac route networks on travel behaviour. Early thoughts in the UK from Marshall (2004).
- Public transport accessibility: Amundsen (1993) reports on the Dutch ABC location policy and Kitamura et al (1997) consider distance from rail stations and bus stops in relation to mode share. Little systematic analysis of accessibility and travel behaviour relationship.
- Green belt: some evidence that green belt designations have led to increases in trip lengths (Elson, 1999; Headicar, 1997). Little systematic analysis of the green belt and travel behaviour relationship.

Further Socio-Economic Variables

- Dual-income households: assessment of how the choice of new housing location is influenced by the location of two workplaces, extent of 'excess travel' and reasons behind it, role of travel factor in choice of location of new home. Little research evident.
- Surrounding mobility levels: impact of surrounding area-wide levels of mobility on individual travel behaviour in terms of mode choice, journey to work length and energy consumption. Some anecdotal evidence in the USA. Little research evident in the UK.
- Attitude: some research in California, USA as to the impact on travel behaviour (Kitamura et al, 1997). Little research evident in the UK.

As we can see, there are many contradictions in the research results, even in the previously researched areas. The reasons for this are numerous, but include:

- Definition of problem: different measures of variables are used in studies, the classic example being definitions of density. Resident population and employment density and workplace population and employment density are all used in earlier studies.
- Data sources: regional, city-wide and/or local area datasets are all variously used.
- Analysis: different research techniques are of course employed, ranging from simple cross-tabulations and descriptive analysis, to more complex multi-variate analysis and simulation studies.
- Location: different geographical areas of research also give varying results. It is not surprising that research from California, USA gives different results to that from Oxford, UK or Perth, Australia, etc.

It is important to understand that there are likely to be a multiplicity of pathways towards different sustainable futures (Guy and Marvin, 2000), but also that the form of a town or city *can* affect its sustainability (Williams et al, 2000) - and as part of this: travel behaviour.

The main research gaps are based around the contradictions in the literature. For example, how can we gain a clearer picture of what is going on on the ground? How do we quantify the strength and significance of known land use variables and what are the ranges of influence? How does travel behaviour change over time and by location? Does 'co-location' of households and employment actually occur? Will efforts to improve physical proximity be less successful in achieving travel reduction in certain areas, perhaps where levels of income and mobility are high? Likewise, proximity to the strategic transport network, good public transport accessibility or green belt designation: what are the likely impacts of these variables on travel behaviour? Each of these research issues and gaps are developed later in the thesis through the use of research questions (see pages 42-58) and the actual empirical analysis (pages 64-327).

1.4 The Sustainable Growth Challenge

At the strategic, cross-sectoral level, the UK Government's Sustainable Development Strategy 'Securing the Future' (Defra, 2005) recognises that the transport sector has a role to play in reducing energy consumption and CO_2 emissions, but makes little mention of the role that urban planning can play in influencing travel behaviour patterns. The UK Climate Change Programme (Defra, 2006) similarly perceives transport as important; yet offers little in the way of measures to achieve carbon reduction targets; certainly the transport sector is not likely to achieve a 60% reduction in carbon emissions as is expected in all emissions. Recent reviews such as Stern (HM Treasury and the Cabinet Office, 2006) reinforce the imperative to act against global warming. Stern is particularly important in demanding an immediate response and arguing that the benefit of strong and early action far outweighs the costs of not acting.

Inertia remains in the transport sector. The Eddington Study (HM Treasury and the Cabinet Office, 2006) concentrates mainly on the links between transport and productivity, hence is very restriced in remit. A new Planning Policy Statement on Transport is expected in the near future - but has been "expected" for quite a few years now.

The lack of knowledge and uncertainty in the research world has perhaps led to this uncertainty in terms of guidance in the transport sector. Within the transport and urban planning sector, guidance issued by the UK Government in the form of the original PPG13 (DOE, 1994a) was able to offer a number of broad principles to influence the planning of development. These included channelling the majority of new development to or within larger urban areas, locating major generators of travel demand in existing centres, and siting development where it is accessible to means other than the private car. The revised PPG13 (DETR, 2001) strengthened the objective of integrating planning and transport at all levels. For example, it was more explicit on the use of a hierarchy of modes, moving from walking and cycling, to public transport and finally, the car. Also it pressed for Local Transport Plans and Development Plans to be developed in a consistent manner, with generators of traffic located at accessible centres or interchanges.

These broad principles are, perhaps correctly, as far as the national transport guidance goes. The way forward at the local level however is unclear, with no real understanding of the relative merits of different urban areas, or whether attempts to increase densities or provide local services and amenities would reduce car-based travel in different ways in different urban areas. There is a real regional and local policy gap here. Regional Planning Guidance or Structure Plans, as yet, don't particularly develop our understanding of the land use and transport relationship beyond the generic PPG13 guidance. They tend to be weak on contextuality. The utility of one planning for all approach in the form of poorly differentiated regional and local planning is limited. Reflecting context is always difficult, yet critical.

Further investigation of the land use and travel relationship is required to help formulate clearer guidance for local implementation through Local Transport Plans and Local Plans (or Local Development Frameworks). It should be noted that we are in the midst of an unprecedented growth of new households in the UK: 4.4 million new households are proposed by 2016 (from a 1991 base[3]). Two in five (1.73 million) of these households are expected to be in the South East: at least 48,000 in our area of interest - Surrey (see Surrey Structure Plan, 2004[4]). The additional pressures are of course where there already is the most pressure for development, and where most controversy surrounds new development. The recently published Draft South East Plan (SEERA, 2005) - the spatial strategy for the region - provides little thought on the strategic location of housing with regard to the potential travel implications. The notions of 'hubs' and 'spokes' are put forward, with development concentrated at key centres, linked by transport corridors, however little empirical analysis appears to lie below this.

The travel generated from the proposed new households could be extremely variable, depending on their location. A more robust understanding of the key determinants of travel patterns is needed in order to ensure that they are located in a sustainable manner. At the moment, mixed messages from the research field mean that the transport arguments are being ignored in discussions of 'optimum' locations for new housing development. There is certainly little agreement as to the quantification of the role of urban planning in achieving sustainable travel.

1.5 A Helpful Analogy and the Nexus of History and Geography

In describing the inspiration for the thesis, and in theorising the nature of the problem to be analysed, authors from the wider urban planning and transport planning fields provide useful context. Three authors are particularly important: Jane Jacobs, David Harvey and Manuel Castells.

Jacobs[5], in *The Death and Life of Great American Cities* (1961), talks about three typical research problems:

1. Problems of simplicity

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[3] DoE (1994) forecasts suggest that in just 25 years we may have to find housing for some 4.4 million households in England alone; and 3.5 million by 2011. This is a huge upward jump, a 70% increase on the previous 25-year forecast of 2.6 million. The forecast growth in households is not due to population growth, but a result of changes in the composition of the population and other wider social changes: many more younger people are leaving home for higher education or first jobs, divorces and separations are growing, older people are living longer, etc. The challenge is to provide for growth in a sustainable manner; even previous modest growth was hotly disputed by local authorities, environmental groups and other pressure lobbies.

[4] The Surrey Structure Plan provides the spatial strategy for the county to 2016 (Surrey County Council, 2004).

[5] A neighbourhood activist, Jacobs was often dismissed as a political and urban planning amateur – 'the little old lady in tennis shoes' - more concerned about personal safety issues than so-called state-of-the-art planning techniques. However, the publication of 'Death and Life' hit the world of city planning with great force when it appeared in 1961. The book was a full frontal attack on the planning establishment, suburban sprawl and bulldozer redevelopment. Jacob's thoughts on urbanism have since become mainstream planning thought.

2. Problems of disorganised complexity

3. Problems of organised complexity

Jacobs expands these research paradigms as follows: *problems of simplicity* are problems that contain two factors that are directly related to each other in their behaviour. The behaviour of the first variable can be described with a useful degree of accuracy by taking into account only its dependence on the second variable and by neglecting the minor influence of other factors.

Advances in analytical methods have led to problems being able to be studied with three and four variables, and on to the other extreme, problems with 100s, 1000s and millions of variables. Physical scientists have developed statistical techniques, which deal with what might be called problems of *disorganised complexity*.

One of the examples Jacobs (p.432) uses to illustrate her ideas is as follows: "*The classical dynamics of the nineteenth century were well suited for analysing and predicting the motion of a single ivory ball as it moves about on a billiard table. One can, with a surprising increase in difficulty, analyse the motion of two or even tree balls on a billiard table. But as soon as one tries to analyse the motion of ten or fifteen [or a million] balls on the table at once, the problem becomes one of disorganised complexity.*" This analogy is particularly useful when considering travel behaviour, and the increasingly complex movement patterns of individuals.

Jacobs' third category of problem tackles a further empirical difficulty where, more important than the mere number of variables, is the fact that these variables are all interrelated. As contrasted with the disorganised situations, these groups of problems are labelled as ones of *organised complexity*.

Drawing parallels with the thoughts of Jacobs, this thesis seeks to examine the land use and travel behaviour relationship as a problem of simplicity, and disorganised and organised complexity.

An additional dimension is also considered within the research. And for this inspiration is drawn from David Harvey (see *Spaces of Hope*, 2000, and other publications[6]). Very little research in the transport and land use interaction field has directly examined the impact of time on travel behaviour. Traditionally, time has been treated as a framework within which social activities are carried out (Giddens, 1979): time and space are perceived to exist independently. Harvey has developed this thinking, considering interdependence, and developing a theory of spatio-temporality.

This thesis tests the data in Surrey for spatio-temporality effects. Much of Harvey's literature is concerned with the effects of market capitalism and how these manifest themselves spatially. In Spaces of Hope, he particularly considers the third dimension of time, introducing the concept of "*spatio-temporality*". By this (and drawing on the writings of Marx, Einstein, Newton, Descartes,

[6] Harvey has written widely in the US; often developing a political angle to the debate on urban issues. He draws on Marxist thinking in the 1970s (see *Social Justice and the City*, 1973) and develops a postmodern cultural studies approach in the 1980s (*The Condition of Postmodernity*, 1989). There are strong analogies with/progressions in thinking from Engels's Marxist view of class relations in 19th Century Manchester (*The Condition of the Working Class in England in 1844*, 1845); Lefebvre (*Le Droit à la Ville*, 1967; and *La Production de l'Espace*, 1974); and Davis's view of urban life in Los Angeles (*City of Quartz: Excavating the Future in Los Angeles*, 1990).

Schumpeter, Foucault and others) he describes the continual change and evolution of geography over time.

For example: "*The history of creative destruction and of uneven geographical development ... is simply stunning ... much of the extraordinary transformation of the earth's surface (over) these last 200 years reflects precisely the putting into practice of the free market utopianism of process and its restless and perpetual reorganisations of spatial forms.*" (Harvey, 2000, p.177-178).

Castells has similarly described the development of a new spatial geography, and the relationship of space and time (1972, 1989, 1996, 1997, 1998 and 2002). For example, he talks about a simultaneous concentration and deconcentration of development, the constitution of new metropolitan areas and mega-regions, a developed network of centres, and networked spatial mobility as "*the new frontier*".

The second theme within this thesis is therefore the impact of time and how this manifests itself spatially. Or as Harvey neatly summarises: the nexus of history and geography.

1.6 The Research Focus

There is therefore a body of research that attempts to understand the logic behind the organised complexity of city development. This thesis seeks to build on this work, but with a focus on urban planning and transport. In particular, the two key dialectic themes developed are those of understanding complexity and spatio-temporality. The topic of research evolves from an understanding and critical review of a rich literature field; ranging from (amongst others) Newman and Kenworthy; and Gordon and Richardson; to Jacobs, Harvey and Hall; Cervero and Kitamura; Burgess, Geddes and Mumford; to Breheny, Banister and Headicar; and Schwanen and Crane.

The thesis examines new household locations and their associated travel behaviour, and asks whether, through an increased understanding of the field, incorporating a wide range of land use and socio-economic factors, and concepts such as complexity and spatio-temporality, we can move beyond Crane's (1999) ultimate planning brick wall – of actually reducing travel by design? In essence: What are the relationships between urban form and travel? Can we quantify the role of urban planning in achieving sustainable travel? Can, and if so how, do we reduce travel by design?

Hence the thesis title: **"Reducing Travel by Design: New Household Location and the Commute to Work"**.

The originality of the thesis lies in moving the land use and transport debate forward, for example by examining the nature of interactions between a wide range of land use and socio-economic variables and travel behaviour; and by assessing the complexity and strength of these interactions. The thesis particularly examines temporal influences and demonstrates how land use and transport relationships change as travel behaviour is modified over time. Travel behaviour is defined in terms of energy consumption, and also travel distance, time, occupancy and mode. The choice of Surrey as a study area is also unusual in that little land use/transport interaction research has previously been carried out in such a 'London-fringe' location. There has certainly been little academic research in the county in the urban planning and transport field; less still from the multi-disciplinary standpoint.

A further thought is important. Goodwin (1999, p.4)[7] has talked about changing travel behaviour as a matter of "asymmetrical churn". Goodwin elaborates: "*I would say that the only successful pathway to substantial change in transport behaviour at the aggregate level is by intervening to secure an 'asymmetric pattern of churn'. This means that we should stop talking in terms of encouraging people to stop driving and start using public transport, but seeking to increase a little the numbers of people who are already, every year, doing just that in huge numbers, and reducing a little the numbers of people who are already, every year, doing exactly the opposite, in equally huge numbers. These are two separate design processes, and they have to be targeted separately.*"

So, an important caveat: even if this thesis progresses our thinking to the next level; even if we have an enhanced understanding as to what is going on in the land use and travel behaviour relationship; even if we believe we can reduce travel by design; there is unlikely to be a huge immediate shift in travel behaviour patterns on the back of a more enlightened national planning and transport policy stance and improved development control implementation. Incremental change or an asymmetric pattern of churn is more likely. The end of (integrated planning and transport) history[8] is not nigh.

1.7 The Shape of the Thesis

The rest of this thesis is thus structured as outlined below and as outlined in Figure 1.2.

- Chapter 2: Literature Review - a summary of the research field; covering sustainability, urban planning, land use and travel interaction; and identifying 'gaps' in the literature and future research areas for analysis in the thesis.

- Chapter 3: Research Design and Method - development of the research methodology, research hypotheses and study questions, including a summary of the research originality. Also providing an overview of the empirical data used in the research and a summary of the dataset.

- Chapter 4: Land Use Influences on Travel Behaviour - including consideration of the impact of density, settlement size, distance from urban centre, jobs and housing balance, local neighbourhood design, public transport accessibility and green belt designation.

- Chapter 5: Socio-Economic Influences on Travel Behaviour - including consideration of the impact of income and car ownership, household composition and attitudes to travel.

[7] See Goodwin's lecture to the Transport Planning Society (ICE, 1999): www.tps.org.uk
[8] A diversion maybe: pretensions towards eschaton (the study of last things) have a long history; Fukuyama is perhaps the most well-known in considering 'the end of history': "*What we are witnessing is not just the end of the Cold War but the end of history as such. That is, the end of man's ideological evolution and the universalism of Western liberal democracy.*" (Fukuyama, 1989).

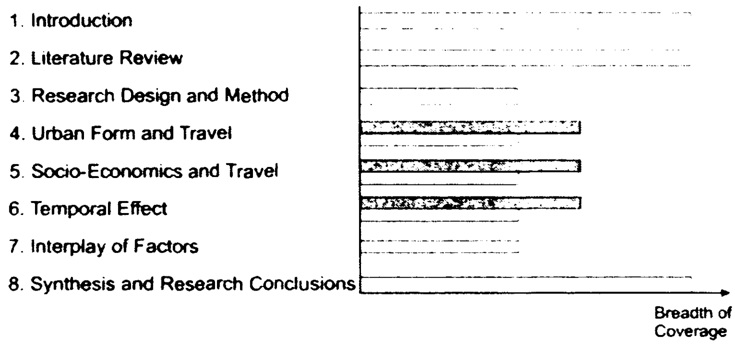
- Chapter 6: The Temporal Effect - a more detailed analysis of changes over time, including consideration of co-location trends by land use variable and urban area niches.

- Chapter 7: The Interplay of Factors – using multi-variate statistical analysis, an assessment of the relative strengths of land use and socio-economic variables in influencing travel behaviour.

- Section 8: Synthesis and Research Conclusions - key study findings and thoughts for future policy interventions and future research.

The breadth of coverage in terms of relation to the wider literature field is at its widest during the first two chapters and the conclusion. Chapters 3-7 are narrower in remit, focusing on the design or analysis of the empirical data in the chosen research area. Chapters 4-6 however commence with reference back to the international literature field.

Figure 1.2: *Structure of the Thesis and Breadth of Coverage*



A number of annexes are also included, which provide further detail to a number of the earlier sections, as outlined below:

- Annex 1: 1998 household survey.

- Annex 2: 2001 household survey.

- Annex 3: Descriptive outputs.

- Annex 4: Energy consumption changes.

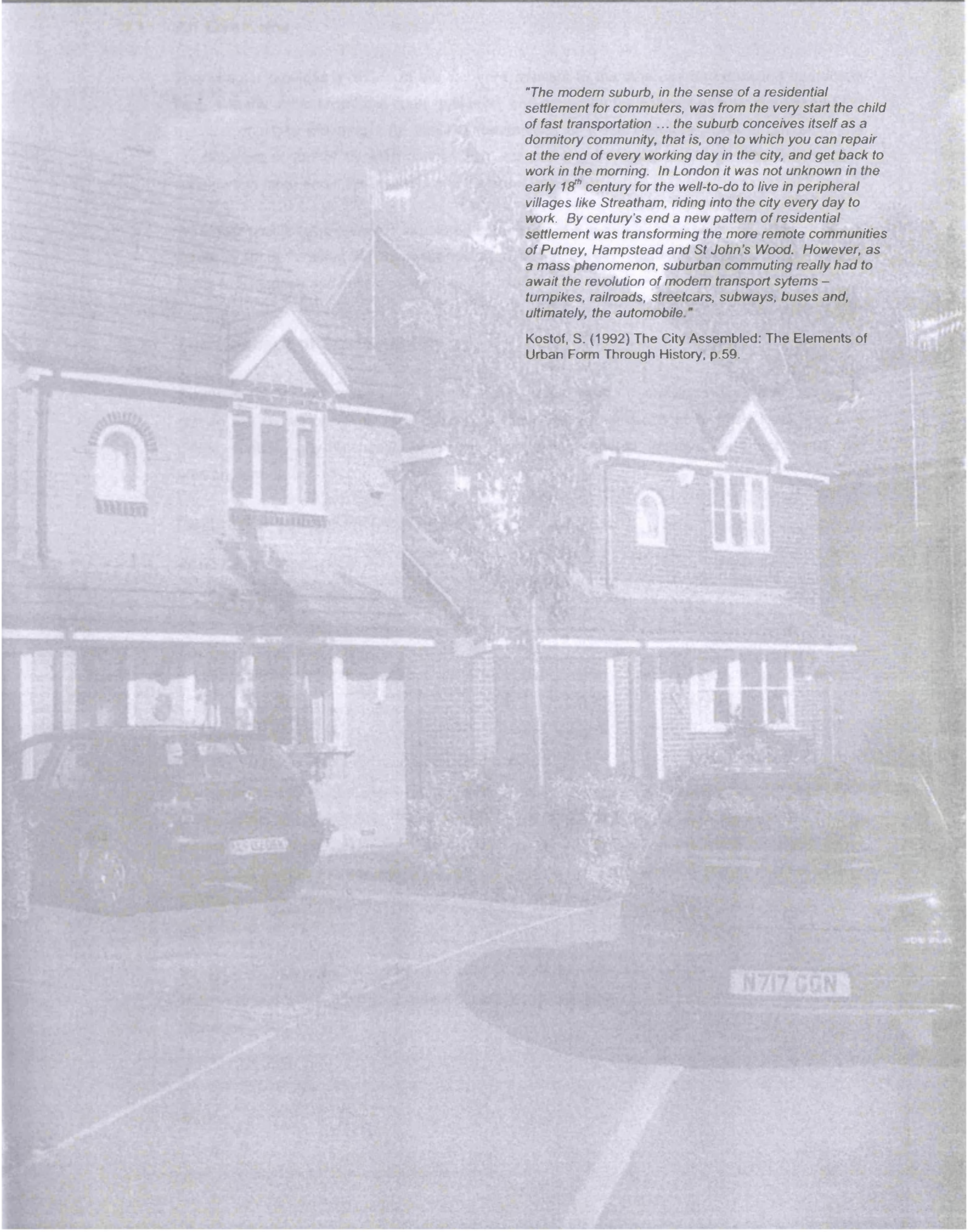
- Annex 5: Inferential statistics additional data.

- Annex 6: References.

02. Literature Review

"The modern suburb, in the sense of a residential settlement for commuters, was from the very start the child of fast transportation … the suburb conceives itself as a dormitory community, that is, one to which you can repair at the end of every working day in the city, and get back to work in the morning. In London it was not unknown in the early 18th century for the well-to-do to live in peripheral villages like Streatham, riding into the city every day to work. By century's end a new pattern of residential settlement was transforming the more remote communities of Putney, Hampstead and St John's Wood. However, as a mass phenomenon, suburban commuting really had to await the revolution of modern transport sytems – turnpikes, railroads, streetcars, subways, buses and, ultimately, the automobile."

Kostof, S. (1992) The City Assembled: The Elements of Urban Form Through History, p.59.



2. Literature Review

2.1 An Overview

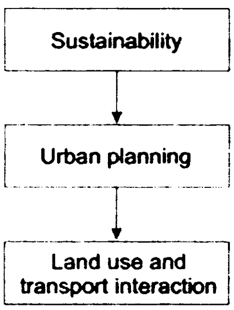
This chapter provides a review of the literature relevant to the land use and transport interaction field. It starts at the broad and contextual level, and considers the concept of sustainability and the tradition of urban planning. An initial understanding of these literature fields is critical to the development of further thinking concerning land use and transport planning. The final section considers in more detail the land use and transport interaction field.

Wherever possible the review is structured in the form of a summary table, with individual pieces of research set out against the key research issues in this thesis. This form of review leads us more easily to a focused and critical analysis of the issues.

2.2 The Concept of Sustainability

Sustainability is the starting point for the thesis, providing the underlying rationale for aiming to reduce the impact of travel. The concept is most easily understood at its basic level: that in a global context, any economic or social development should improve, and not harm, the environment.

Figure 2.1: *Structure of the Literature Field*



Sustainability has become one of the most diversely interpreted concepts among academics, professionals and the public. There remains much uncertainty as to what sustainability actually means in definitional terms. There is certainly no universally accepted definition of sustainability, sustainable development or, indeed, sustainable cities and sustainable transport. Guy and Marvin (2000) perhaps make the critical point: there is a multiplicity of pathways towards different sustainable futures.

To help structure our thoughts, this section considers the key political events, sustainability principles, additional definitions, progress towards global environmental targets, and 'deeper green' thinking.

2.2.1 Global Political Progress

The political history is well documented. Houghton (2004) gives a thorough overview[9]. First discussions of sustainability emerged in the global arena at the 1972 United Nations Conference on the Human Environment in Stockholm. Here, 113 nations pledged to begin cleaning up the environment and to begin the process of tackling environmental issues on a global scale, recognising that the problems of air pollution, water pollution and chemical contamination did not (and still do not) recognize national borders.

In 1983, the UN established the World Commission on Environment and Development in an attempt to solve the problems involved with Third World development and future resource usage. Much emphasis was given to the estimated one billion people living in poverty and with food shortages.

In 1987 the Commission published *Our Common Future* (otherwise known as the Brundtland Report), which launched into common usage the phrase 'sustainable development'. This was given more form at the Earth Summit in Rio de Janeiro in 1992. Two major follow-up summits have been held: Kyoto in 1997 (concentrating on environmental issues) and Johannesburg in 2002 (with a greater focus on poverty and development issues). A series of intermediate meetings have been held at cities such as The Hague, Marrekesh, Bonn and Milan, and most recently Montreal (2005).

A number of evolving aims and targets have been developed at these key conventions and their associated meetings. *This Common Inheritance* (DOE, 1990) committed the UK Government to reducing the upward trend in CO_2 emissions, provided that other countries undertoook similar actions. The Climate Change Convention in Rio de Janeiro in 1992 committed the UK to reducing CO_2 emissions to 1990 levels by 2000.

In Kyoto, industrialised nations agreed to an average cut in emissions of 5% below 1990 levels by 2012. Individual targets ranged from an 8% reduction in the EU, a 7% reduction in the US to an 8% increase in Australia. After the protocol was signed, the EU agreed to reallocate its entitlements so countries like Ireland and Spain could increase their emissions, while Britain and Germany compensated by making higher forecast cuts. The UK agreed to reduce emissions by 12.5% below 1990 levels by 2012. More recently the UK Government adopted a more stringent policy goal of a 20% reduction in carbon emissions from the 1990 level by 2010 (restated in the 2004 Spending Review) and to following a pathway towards a 60% reduction in carbon emissions by 2050 (DTI Energy White Paper, 2003).

The Stern Review (HM Treasury and Cabinet Office, 2006) has been influential in considering the economics of climate change, and reinforcing the need to act quickly against climate change. Edidngton (HM Treasury and Depatrment for Transport) has similarly had an economic focus, but in considering transport and productivity.

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[9] Much more has been written on sustainability and key issues such as global warming. A good starting point for information is the Tyndall Centre for Climate Change Research, see www.ukcip.org.uk; the Hadley Centre for Climate Prediction Research, see www.met-office.gov.uk/research/hadleycentre; or the US Environmental Protection Agency, see http://yosemite.epa.gov/oar/globalwarming.nsf/content. Hillman and Fawcett (2004) give an interesting overview - typically polemic - of the transport sector and its relationship with global warming.

In political terms, progress has thus been slow but far-reaching. Two decades ago, few people outside the research community had heard of climate change. Countries have however found it difficult to meet their emissions targets. Latest forecasts expect the UK to meet the Kyoto target (helped in the main by the closure of much of the coal mining industry) but miss the more stringent national policy goal - of a 20% reduction on 1990 levels - by up to 8% (Cambridge Econometrics, 2004).

2.2.2 Principles of Sustainability

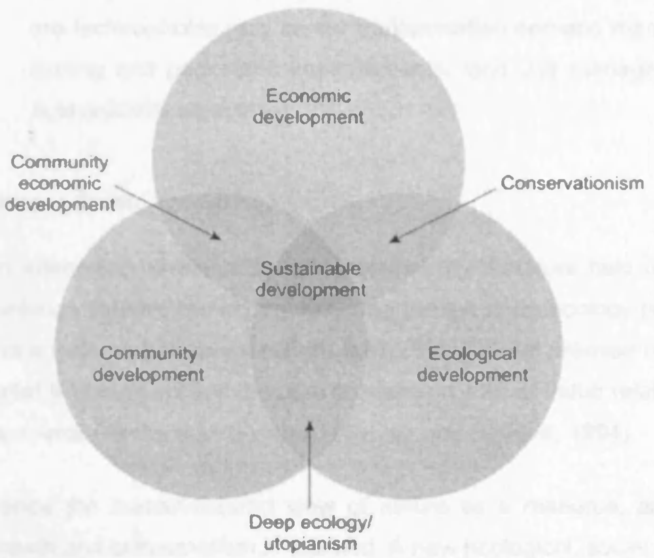
Sustainability has been presented as an agenda to simultaneously solve global environmental problems and to facilitate the economic development of the poor, particularly those in the Third World (Newman & Kenworthy, 1999). Four principles can be derived from the 1987 Brundtland Report:

- The elimination of poverty, especially in the Third World, is necessary not just on environmental grounds, but as an environmental issue.
- The First World must reduce its consumption of resources and production of wastes.
- Global co-operation on environmental issues is required.
- Change towards sustainability can only occur with community-based approaches which take local cultures seriously as well as the more traditional top-down approaches.

The concept of sustainability has therefore emerged from a political process which has attempted to bring together three broad themes (see Figure 2.2):

- The need for economic development to overcome poverty.
- The need for environmental protection of air, water, soil, and biodiversity.
- The need for social justice and cultural diversity to encourage local communities to express their own aspirations for future development.

Figure 2.2: *The Three Pillars of Sustainable Development*



(Based on International Council on Local Environmental Initiatives, 1996)

2.2.3 Varied Perspectives

Sustainability can also be viewed from various perspectives. These often reflect basic values and as such it is difficult to put forward a 'right' or 'wrong' position in terms of preference. Appreciating the differences can however help resolve conflicts and achieve co-operation between stakeholders. Below are examples of some of the views (based on Crane, 1999):

- Anthropocentric versus deep ecology: some sustainability issues are affected by the value placed on ecological resources. Valuation is often based primarily on possible human impacts, reflecting an 'anthropocentric' (or human-centred) perspective. A 'deep ecology' perspective considers ecological integrity as an end in itself. An example of these alternative perspectives is the debate over the costs of climate change emissions. A (tiny) minority of researchers argue from an anthropocentric perspective that global warming may be beneficial overall because increased CO_2 and warmth will increase agricultural production, while experts with a deep ecology perspective argue that disrupting ecological systems is inherently wrong.

- Rich versus poor: some of the materially wealthier nations are often accused of ignoring equity issues and the immediate environmental and quality of life issues affecting poorer countries. For example, the USA demands that developing countries take more responsibility for reducing climate change emission, since much of the expected growth in emissions will be in these countries. The developing countries argue that the wealthier, industrialised countries reduce their existing high rates of per capita emissions (since the overwhelming majority of emissions are generated in the 'developed' West).

- Technopositive versus technophobic: a 'technopositive' perspective assumes that new technologies are likely to provide the best solutions to most problems, while a 'technophobic' perspective sees new technologies as creating and exacerbating most problems. People who are technopositive may (stereotypically) favour nuclear power, alternative fuels, intelligent transportation systems, vehicle design improvements, and other technological solutions to achieve sustainability objectives (all these are not mutually inclusive of course). People who are technophobic may favour transportation demand management strategies, including transit, cycling and pedestrian improvements, land use management, and traffic calming to achieve sustainability objectives.

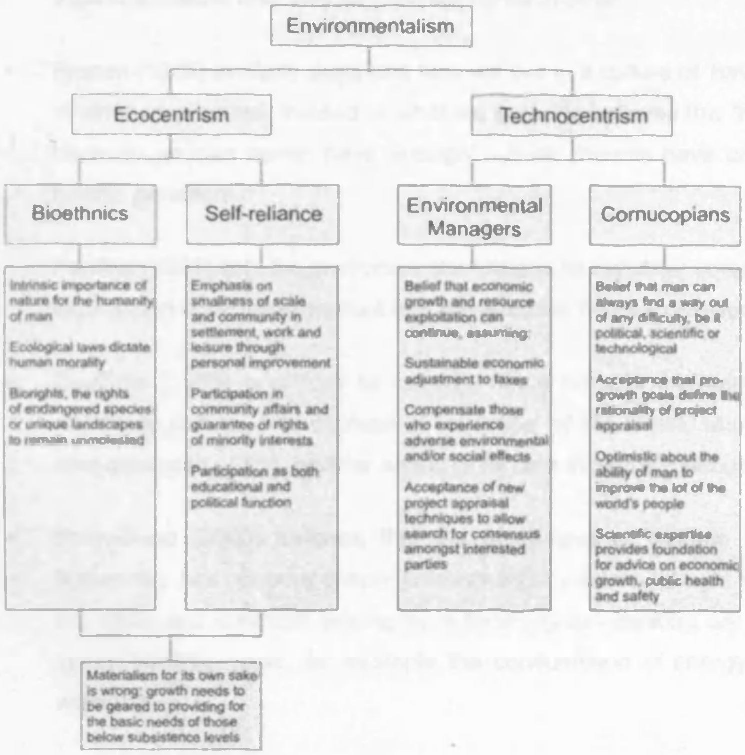
2.2.4 'Deeper Green' Thought

An interesting diversion in the sustainability literature field is the development of 'deeper green' thinking. Referred to above by Crane (as the deep ecology perspective), deep green thought itself has a wide and distinct literature field. The general premise of deep green positions is to reject the belief that humans are the sole or highest order of value relative to other things in the world, such as animals or the environment." (Sylvan and Bennett, 1994).

Hence the human-centred view of nature as a resource, and the 'endless' pursuit of economic growth and consumerism is rejected. A new ecological, social, political, cultural (and spiritual) future is envisaged where the natural environment has a central role and intrinsic value. Within the literature there are a wide variety of viewpoints and subtleties.

O'Riordan and Turner (1983) offer an insight into the differing 'shades' of green thought, as shown in Figure 2.3. In explaining the diagram, the UK government can be argued to have moved from a cornucopian approach in the 1980s, to something more akin to environmental management lines at present.

Figure 2.3: *Environmental Ideologies*



(O'Riordan and Turner, 1983)

Whether mainstream thought will continue to progress towards deeper green thought is open to question. There is still much debate as to whether deeper green thought is the 'real truth' or 'pseudo-science'.

In the literature, various concepts have however been developed. Schwarz (2000) provides an overview of 'deep green' environmental issues, selecting his essential reading material. He describes how the new green worldview has led to a growing scepticism about economic prosperity, materialism and so-called 'development'. Of the leading authors in the field, the following are perhaps the most well known:

- Carson (1962) is often described as having launched the 'modern' green movement with a famous attack on the use of chemical pesticides.
- Schumacher (1973) redefined green economics in his review of the structure of the western world. Schumacher maintained that the pursuit of profit, which promoted large organisations and increased specialisation, in fact led to gross economic inefficiency, environmental pollution and inhumane working conditions. He challenges the doctrine of economic, technological and scientific specialisation, and proposes a system of intermediate technology, based on smaller working units, communal ownership, and regional workplaces utilising local labour and resources.
- Lovelock (1998) goes further, setting out his Gaia hypothesis; he perceives the earth as a living organism whose unique atmosphere sustains life.

- Marshall (1992) attempts to make a link between some of the newest green ideas and ancient ideologies such as Buddhism. He advocates social ecology: the idea that people cannot stop exploiting nature until they stop exploiting each other.

- Fromm (1976) similarly describes how we live in a culture of 'having', which defines us in terms of what we possess, instead of what we are. He believes this 'heresy' is leading us to despair because we can never 'have enough'. Such themes have become key to the deep green holistic paradigm.

- Ponting (1991) sets the environmental crisis in its historical context, comparing the present day exploitation of the environment and the potential future to previous collapses of civilisation.

- Caulfield (1985) is a "call to action", which brought the rainforest, and its destruction, to worldwide notice. Her account of the 'rape' of the forest, why and how it happens, and the consequences of this, was far ahead of its time in warning about climate change.

- Shaw-Bond (2000) believes that the enlightenment attitude towards nature as a tool for humankind has become deeply entrenched in western thought and contends that a number of the ideas and concepts arising from recent green thinking are increasingly used outside the 'green bioethic world', for example the consumption of energy and its contribution to global warming.

A number of other ecological authors are also well cited, for example Hardin (1968), Goldsmith (1972), Meadows (1972) and Eyre (1978). Others, such as Daly and Cobb (1994) and Jacobs (1995), provide yet further perspectives on green issues, particularly in terms of the social and economic dimensions. A number of authors also critique the ecological perception of life: Beckerman (1994 and 1995) is perhaps the most well known of these.

2.2.5 Sustainability in the Transport Sector

Sustainability in the transport sector is also not clearly defined. The Transport White Paper (DfT, 2004c) provides the UK Government's policy approach, yet has been criticised for, amongst other things, not seeking to reduce carbon emissions – presumably a key "sustainability" objective - to a great enough extent (Hickman and Banister, 2005b). The South East Plan (SEERA, 2005) and Surrey Local Transport Plan (SCC, 2001/06) provide the regional and county perspective. Eddington (HM Treasury and DfT, 2006) and Stern (HM Treasury and Cabinet Office, 2006), as previously discussed, also provide a particular angle on the issues.

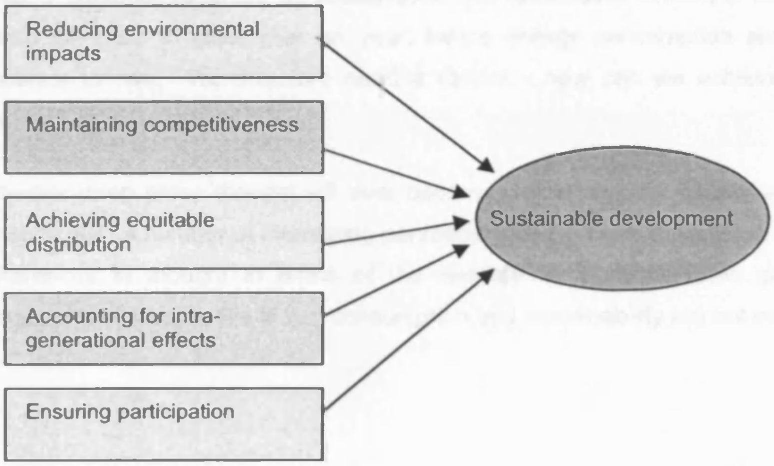
Banister (1998a) gives some consideration to definitions of sustainability in the transport and environment field, using an objectives-based approach, i.e. through what is meant by seeking to achieve sustainable development:

- First, environmental objectives can be looked at in terms of the environmental costs of transport: pollution, resources, environment and development.

- The second objective is to maintain competitiveness through economic growth and development. Where possible, the environmental and development objectives should be working in the same direction, i.e. the 'win-win' situation, or the 'green-gold coalition' (Goodwin, 1991). Recent Governmental policy guidance in the UK (for example, the Transport White Papers, 1998 and 2004) gives emphasis to this approach, and many transport investment decisions have tried to achieve these benefits (see Banister and Berechman, 2000; or Hickman and Banister, 2003).

- In addition to these two fundamental objectives, concerns over sustainability open up new objectives. Issues of equity are concerned with the distribution of costs and benefits with society, both socially and spatially.
- These intra-generational effects can be compared with the inter-generational objectives, i.e. futurity. These can be highlighted by the most often quoted definition of sustainable development, namely: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987).
- The final objective is participation – there is a strong literature devoted to the participation topic (see Arnstein, 1969; through to, for example, Wates, 2000) and the various qualities and impacts of different techniques, perhaps reflecting that, in the past, decisions have been made without the support of affected parties.

Figure 2.4: *Sustainability - An Objectives-Based Definition*



Clearly there needs to be a renewed focus in the future on reducing energy consumption, meaning the promotion of non-car modes and more energy-efficient and carbon-efficient vehicles (the increases in energy consumption and carbon emissions are closely correlated).

In terms of analysis of travel behaviour and moves towards (or away) from sustainability objectives, there is a large body of literature analysing commuting patterns. The Office for National Statistics[10] provides access to Census data allowing individual analysis of data. There is much regional and local authority analyses of data available. SEEDA et al (2005) provide analysis of commuting flows in the South East using 2001 data; many of the multi-modal studies provide rigorous analysis of

[10] See (http://www.statistics.gov.uk)

commuting patterns in the South East – for example the Orbit Study (DfT and Kellogg, Brown and Root, 2002). Surrey County Council (1996 and 2004b) provides analysis of the 1991 and 2001 Census at the county level. Dargay and Hanly (2003/04) provide panel analysis of other types of commuting data, such as household panel surveys. The use of panel surveys is discussed further in Chapter 3, particularly in relation to attrition issues.

Carbon emissions from road transport are expected to be around 14% higher in 2010 than in 1990. Given that the transport sector accounts for over 20% of the UK's CO_2 emissions (DfT, 2004c), continued transport growth is a key obstacle to achieving domestic carbon and energy reduction goals. Certainly the transport sector appears to be under-performing in contributing to cross sectoral targets.

The urgent imperative now is to increase the performance of the transport sector in reducing energy consumption and carbon emissions. Sectoral specific target for transport energy consumption and emissions would be a useful first step.

2.2.6 Conclusions on Sustainability

The rise of sustainability and its wide-ranging use as a working concept has been dramatic since the 1970s. Sustainability is now at the heart of much of the guidance eminating from the UK Government. The difficulty however is that people interpret the sustainability principle in many different ways. And despite much postulation, many key trends are moving in a counter direction to what is generally regarded as sustainable. This is certainly evident in the transport sector - traffic levels continue to grow year on year, hence energy consumption and carbon emissions also continue to rise. We therefore need a rethink - how can we achieve changed trends on the ground?

Whether deep green thought will ever become mainstream thinking clearly has to be questioned. Despite this, a number of interesting perspectives have been developed. Figure 2.5 shows the key differences in thought in terms of the relationship with economic growth: the environmental management perspective is that consumption and sustainability are not mutually exclusive.

Figure 2.5: *Sustainability and Growth*

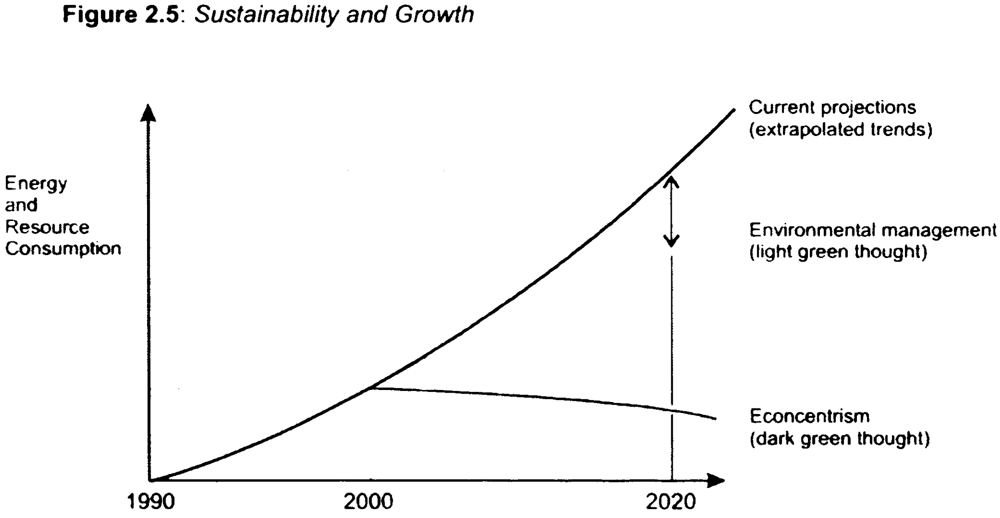


Table 2.1 summarises the issues involved with sustainability and deep green thought and provides a linkage with the developing thinking in this thesis. In essence, the literature provides important context to the issues discussed later in this thesis: sustainability is the underlying justification for seeking to reduce energy consumption in travel. Hence the definition of sustainability used within the thesis is as defined by Brundtland – "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" – but with the focus on reducing journey lengths, reducing car dependency and energy consumption in the commute to work.

Table 2.1: *Sustainability Issues and the Thesis*

Sustainability/Green Issue	Relationship with this Thesis
Three pillars of sustainable development: environment, economic and social (the Brundtland Report, 1987)	Sustainability provides the underlying rationale behind the aim of reducing energy consumption. Energy consumption is the main travel behaviour measure used throughout the analysis in this thesis.
Differing perspectives on sustainability (e.g. Banister, 1998a and Crane, 1999)	Important context for later understanding of the urban planning and land use/transport interaction literature fields.
Deeper green thought (e.g. Goldsmith, 1972; Lovelock, 1989)	Fundamental questions as to the validity of some of the research, but still important context for later understanding of the urban planning and land use/transport interaction literature fields.

2.3 Urban Planning

Attempts to understand, rationalise, and ultimately design 'better' urban form, have a long history, and are intrinsically linked to the wider sustainability debates. Interestingly they have a longer history than the sustainability debates. Not surprisingly urban planners consistently comment that they have been talking about 'sustainability issues' for years; certainly prior to the 1970s when the sustainability concept gained early credence. The world has caught up with the urban planning debate it seems.

Objectives for various urban planning interventions have differed, but have mainly been targeted at improving the quality of life in and sustainability of towns and cities. A number of publications give good commentary, for example Soja (2000), Hall (1988a and 1998) and LeGates and Stout (2000). The essential readings are numerous, reflecting the rich and varied and international literature field. A number provide critical context to the more specific land use and transport interaction literature detailed later and the themes developed during the thesis. These are summarised in Table 2.2, with commentary showing the relationship to the thinking in this thesis.

Table 2.2: *The Urban Planning Classics and this Thesis*

Urban Planning Text	Relationship with this Thesis
Friedrich Engels (1845) *The Condition of the Working Class in England in 1844*. One of the earliest masterpieces of urban sociology, developed as a result of Engels' studies – as a startingly young 24-year old - into business management in the factories of Manchester. The description of the social misery of working-class life is developed into a summary of socialist theory of the origins and historic role of the industrial working class (reflecting and drawing on the works of Marx) at the time of the Industrial Revolution. Much of the argument is constructed by Engels walking around the neighbourhoods of Manchester; including Old Town, Irish Town, Long Millgate and Salford.	Engels provides an early example of descriptive narrative concerning the state of the urban environment. The later analysis in this thesis and particularly the case study material develops a similar approach with detailed, micro empirical analysis, from which more general findings can be developed. Engels' cross-disciplinary nature, understanding the urban environment as a reflection of society itself, is the basis for later thinking, for example from the Chicago School, and also in this thesis: changing travel behaviour is a reflection of changes to urban form and wider societal and economic change. The premise is that there is a logic to city development, though often difficult to understand. It is worth seeking for - if we can understand it we can influence it to our mutual benefit.
Ebenezer Howard (1898) *Garden Cities of To-morrow*. Born in London, Howard experienced the pollution, congestion and social problems of the modern industrial metropolis. After five years in the USA, he returned to England in 1876 and became involved in political movements addressing what was then termed 'the social question'. Howard was influenced by a number of radical theorists and visionaries, such as the social reformer Robert Owen and utopian novelist Edward Bellamy, and published in 1898 To-morrow: A Peaceful Path to Real Reform (now better known under its 1902 title, Garden Cities of To-morrow). His vision of urban decentralisation, zoning of different uses, integration of nature into cities, green belts, and the development of self-contained new town communities around crowded central cities, laid the groundwork for the entire tradition of modern town and country planning. Howard lived to see his ideas translated into the garden cities of Letchworth and Welwyn. However, many of the original goals became compromised: building lots and businesses were privately owned, the greenbelt was often shared with ad-hoc development and never became an extensive rural buffer zone, and neither of the original garden cities ever became independent economic entities.	Howard provides the basis for much of present day urban planning thought. The town-country magnet is potentially a way forward for areas such as Surrey and certainly offers important context to thinking on new housing location. Described in further detail on page 35, Howard provides guidance on strategic planning, the town/country buffer, green belts and the development of communities around a public transport system, all of which are critical concepts for this thesis. Howard provides a critical foundation for thinking in this thesis - that we can strategically integrate urban planning and transport.
Ernest Burgess (1925) *The Growth of the City: An Introduction to a Research Project*. Interestingly, sociologists rather than geographers developed the modern field of urban geography. One of these pioneers was Burgess, who was a member of the Chicago school of urban	Burgess's recognition that there might be an underlying logic to the physical form of places - and the spatial representation of this - is critical, as is the city as a dynamic organism that

sociology - a group of researchers, which included Louis Wirth and Robert Park, based at Chicago University in the 1920s and 1930s. The body of research developed by the school includes some of the most well-known studies concerned with the understanding of urban ecology. Burgess argued that there was an underlying logic to the physical form of cities and developed the concentric zone model, which depicted the city as a neat representation of annular rings emanating from the central business district. Each ring had a distinct set of residents and functions; physical form and human life were intimately linked. And, cities were not static; they were dynamic organisms with a constant flow of new residents coming into the inner rings and a flow from these rings outwards over time. Burgess's research inspired a generation, and more, of future researchers. Today it remains ever relevant.	changes over time - an urban metabolism - with a constant flow of new residents from one part of the urban area to another. These concepts are important to this thesis, which asserts that there is an underlying logic to travel behaviour in Surrey (however complex this might be). The temporal dimension is also pursued as a particular theme throughout much of the analysis.
Lewis Mumford (1961) *The City in History*. Mumford saw the urban experience as an integral component in the development of human culture and human personality. For over 60 years he sparred with those who argued that cities arose and prospered for purely economic reasons or that cities were best defined in terms of size and density. For Mumford, cities were expressions of the human spirit, existing to contribute to the ever-evolving human personality: "*the city's streets are a stage on which life's drama is played out*". A strong influence on urbanists - such as Jane Jacobs, William Whyte, Allan Jacobs and Donald Appleyard - he argued that creating better, more humane cities would enrich civilisation itself.	Mumford develops the idea that urbanity is a wider reflection of human culture and societal changes over time. This thesis similarly postulates that life in Surrey - including housing and workplace location and travel behaviour - reflects wider changes in society: the nexus of history and geography. Also the determinism of improved urban experience is a forerunner to developing human culture.
Jane Jacobs (1961) *The Death and Life of Great American Cities*. Jacobs questioned (the then) universally accepted articles of faith – for example, that major urban clearance projects were good and that crowding was bad. Indeed she suggested that crowded sidewalks were the safest place for children to play. Safety, particularly for women and children, comes from 'eyes on streets' and a sense of personal belonging and social cohesiveness from well-defined neighbourhoods and narrow, crowded, multi-use streets.	Jacob's unabashed love of cities and concern in improving the quality of urban life has been hugely influential in developing later new urbanist and urban renaissance thought. Interestingly the urban/rural/suburban fringe has received less commentary. Jacobs' thoughts on simplicity, disorganised and organised complexity are also important to this thesis.
David Harvey (1992) *Social Justice, Postmodernism and the City*. Harvey develops a cultural/philosophical angle to the debate on urban issues. Harvey draws on his 1970s Marxist thinking (see 'Social Justice and the City', 1973) and his postmodernist cultural studies approach in the 1990s ('The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change', 1990). There are also strong analogies with/progressions in thinking from Engels, Lefebvre, Castells and Davis.	Harvey provides some of the theoretical framework for this thesis. He has greatly widened the debate on urban issues, using multi-disciplinary thinking in geography, urban planning, sociology, history and politics. This wide-angle approach to research is replicated in this thesis, particularly looking at the nexus of history and geography (using the concept of spatio-temporality) and the integration of transport and urban planning.
Manuel Castells (1993) *European Cities, the Informational Society and the Global Economy*. Castells is one of the great contemporary analysts of urban society and has carefully analysed the likely near-futures of urban life. Castells considers the effects of economic globalisation and new information technologies on future urban form. He argues that technology-based cities represent 'a new industrial space', located in centres throughout Europe, Asia and America, are tied to a global 'informational' economy, and are fundamentally different to anything that has come before. A two-tier economy and a widening gulf between the educated elites and the ghettoized, marginalised urban populations is intensifying. In a later publication ('The Rise of the Network Society', 1998), Castells argues that the workstyles of this post-industrial economy are becoming detached from traditional cultures, values and communities: "*the historical emergence of the space of flows supersedes the meaning of the space of places*." For Castells, the real challenge is to reconcile the "new techno-economic paradigm" in a way that will avoid what he calls "urban schizophrenia".	Castells also provides additional important theoretical groundwork for this thesis. Publications from the early 1970s onwards (The Urban Question, 1972) have consistently pushed at the boundaries of thinking. The underlying theme throughout much of the Castells research has been to understand and explain urban development within its wider societal context, and critically then to move on and attempt to develop an improved quality of life from the collection of disparate communities and individuals. The challenge is to develop this thinking in Surrey.
Saskia Sassen (1994) *Cities in a World Economy*. Rapid and fundamental changes in the world economy are clearly impacting on the evolution of cities today. Sassen carefully examines the economies and workforce characteristics of the largest global cities and the way in which they interact with other cities in the world economy. She argues that a number of 'global cities' – where banks, corporate headquarters and high-level producer/service businesses such as law firms and advertising agencies are concentrated – have emerged as strategic places in the world economy. Decisions made in London, Tokyo, New York or Sidney affect jobs, wages and the economic health of locations as remote as Kuala Lumpar, Malaysia or Sao Paulo, Brazil. Sassen argues strongly against authors such as	The Sassen world city thesis has direct relevance to research in Surrey: decisions made in the City of London (and indeed in other major cities around the world) eventually feed their way through to local housing market and travel behaviour patterns. The Surrey housing market plays a number of roles, one of them being a housing provider for World City employees in London. Long distance radial rail commutes into Central London and tangential car commutes to the M4 corridor make up an important part of travel patterns in Surrey. These are inextricably

Melvin Webber (The Post-City Age, 1968) who forecast that instant global communications and an inter-connected world economy may make place unimportant and lead to the end of cities. Sassen's research argues that the global cities' wealth and power is growing rather than declining, whilst many cities that have historically served as manufacturing centres in Europe, North America and Australia – for example: Glasgow, Liverpool, Essen, Detroit, Buffalo and Cleveland - are in economic decline as manufacturing shifts to Asia, South and Central America and elsewhere in the Third World. Sassen also questions the simplistic notion of 'rich' and 'poor' countries and cities; places central to the world economy and those that exist at the margin. She argues that cities at the centre of the world economy are increasingly both rich and poor and that many Third World cities – while economically subordinate to global command centres – are also increasingly stratified by income.	linked to the economic changes identified by Sassen.
Peter Hall (1988a) *Cities of Tomorrow: An Intellectual History of Urban Planning and Design in the Twentieth Century*. The consummate biographer of the urban planning field, Hall takes us on a tour of cities of the garden (Hampstead and Letchworth), the region (Edinburgh, New York and London), beautiful (Chicago, New Delhi and Berlin), radiant (Paris, Chandigargh and Brasilia), sweat equity (Lima and Berkeley), the highway (long Island and Los Angeles) the theory (Philadelphia and Manchester), etc. - via 1960s systems analysis and 1970s Marxist theory.	Pre-requisite reading for any analysis of urban planning in the UK. With Harvey and Castells, Hall leads the current field in attempting to further understand urban development. Other Hall publications - such as Cities in Civilisation (1998), Sociable Cities (1998) and Working Capital (2003) - again help to provide a theoretical and conceptual framework for the thinking in this thesis.

2.3.1 Conclusions on Urban Planning

The urban planning classics, and there are many more than documented here (others, for example, include Sitte, 1889; Wirth, 1938; Mumford, 1937; Geddes, 1915; Le Corbusier, 1929; Jacobs and Appleyard, 1987; and Porter, 1990; etc. etc.), provide the critically important theoretical foundation for the evolution of thought contained in this thesis. Much of the original thought which follows - on topics such as the existance of an urban metabolism, an inherent logic behind complex housing location decisions, interactions with travel behaviour and the influence of temporality and organised complexity - is based on previous 'platforms' of thinking.

2.4 Land Use and Transport Interaction

2.4.1 An Overview

The literature dealing specifically with land use and transport interactions can be viewed as a sub-field of the wider sustainability and urban planning debates. It has developed from the late 1980s onwards and has come to include a rapidly expanding literature. As noted previously, within the field there still remains considerable disagreement and a number of 'knowledge gaps'. Below a fuller review of the literature field is given than that in the introductory chapter. Again - wherever possible - the literature is related to the thesis topic to help provide a structure and focus to the reading. Further thoughts from the literature field are shown in Chapters 4-6 (pages 64-270) as introductory sections to the main empirical analysis in the thesis. This is a different treatment in terms of literature reviewing to many other theses, however is useful in focussing our (and previous) thoughts on the study research questions.

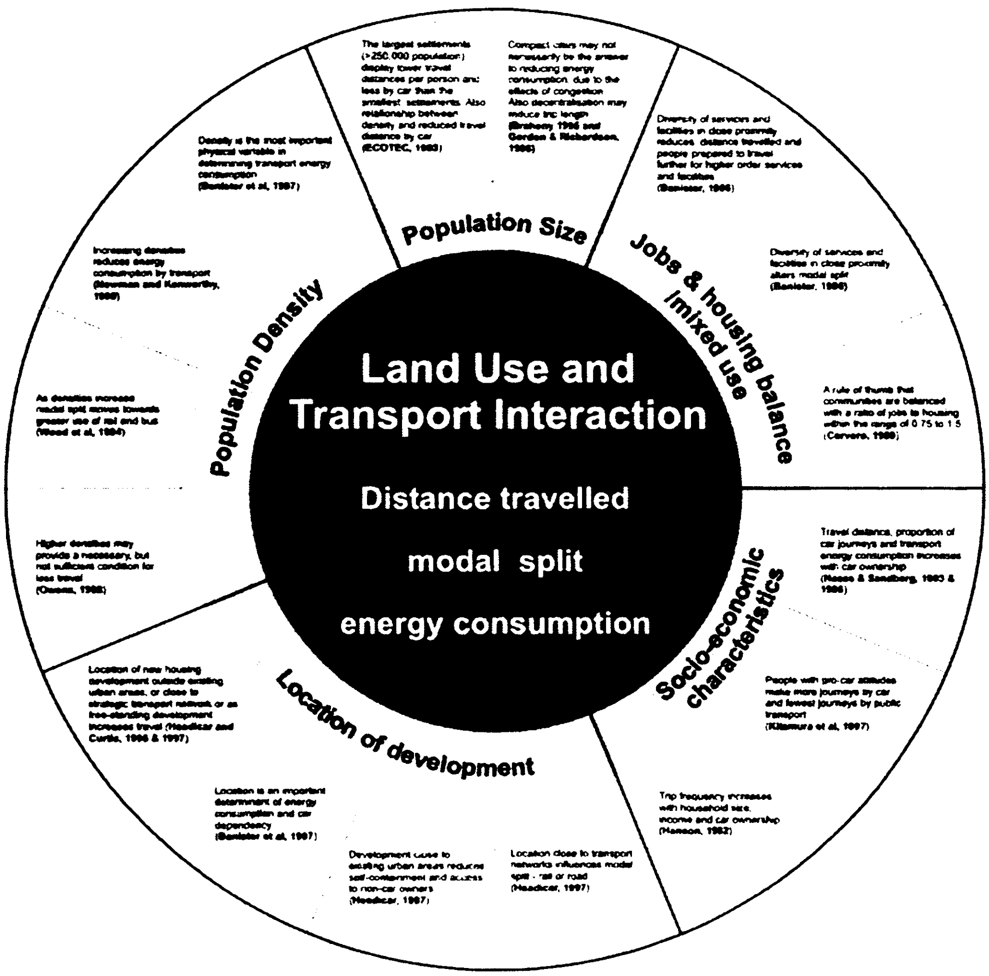
Academic debate as to the potential for structuring urban form to influencing travel behaviour has been mainly carried out in the UK, the rest of Europe, the US and Australia. The underlying theme of much of the research has been to evaluate the potential contribution of land use planning in reducing car-based travel. Two broad camps of research were described in the introductory text to this thesis - the interventionists and the sceptics - in terms of their views on the efficiency of planning as a tool for intervention.

A number of topic areas have received considerable coverage in the literature, such as: the influence of population size, density, the provision and mix of local facilities, local urban form, the location of development, balance of jobs and housing and also wider socio-economic variables. Stead (1999) has brought a number of these areas together using regression analysis. For example, he suggests that socio-economic variables explain between 19-24% of the variation in distance travelled and land use variables up to 3% at the individual level of analysis. At an area-wide level this influence increases: socio-economic variables explain between 23-55% of the variation in distance travelled and land use variables up to 27%.

Conflicting messages however arise from the wider field. Debate remains as to the relative contribution of each variable in terms of influencing travel behaviour.

Figure 2.6 highlights the main land use variables which are most often noted as influencing travel behaviour. It adds to the diagram shown in Chapter 1 (Figure 1.1) by also showing some of the key research findings by author.

Figure 2.6: *Land Use Impacts on Travel Behaviour*



Further estimates have been made to suggest that travel demand could vary, in theory, by a factor of two or three between the most and least efficient land use patterns. However, many of the studies from which these results are derived were conducted in the US, where land use patterns are distinctly different to those in the UK. The UK, as yet, does not have the extent of sprawl as found in the US, and as described in Garreau (1991)[11]. Trends are however working towards that edge city life, and visits to many UK towns increasingly remind us of such dystopian futures. Modelling work in the UK by ECOTEC (1993) has suggested that land use planning measures could achieve a 10%-15% reduction in carbon dioxide emissions over 20 years in a large urban sub-region. The work of Newman and Kenworthy (particularly 1989a and 1999) is worth highlighting at the start of any literature review in this field. They initiated a large body of research by stating that there might be a relationship between population density and energy consumption. Many authors were inspired to reply and we return to these discussions later. Below we consider some of the Newman and Kenworthy thoughts from 1999: distinguishing how three broad types of towns and cities have developed based on their transport infrastructure.

- The walking city: the traditional walking city is characterised by high densities: perhaps 100 to 200 persons per hectare, mixed land uses and narrow streets which reflect the character of the landscape, with most people within 30-minute walks of most parts of the urban area (see Figure 2.7). Few towns or cities today rely entirely on walking as the means of transport, however many neighbourhoods retain these qualities – see for example, parts of Cambridge and York in the UK; Delft and Amsterdam in the Netherlands; North End in Boston, US; or the West End of Fremantle, Perth, Australia.

- The public transport city: from the late 1800s in Europe, the old walking cities began to collapse under the pressure of population and industry. A new city form developed based around a public transport system, accommodating more people at sometimes reduced densities, but with similar 30-minute accessibility patterns. Urban areas pushed increasingly outwards as the train (steam and then electric) and tram and streetcar allowed faster travel to occur. The trains created sub-centres at railway stations that were 'small cities' with walking-scale characteristics (see Figure 2.8). Urban areas could now spread 20-30km based on the new technologies.

- The automobile city: beginning prior to the Second World War, and accelerating hugely afterwards, the private motor car, supplemented by the bus, progressively became the dominant transport technology which shaped urban form. It became possible to develop in any direction, out as far as 50km for the average 30-minute journey time. Densities declined – to as low as 10 or 20 persons per hectare – and car dependent cities and towns developed (see Figure 2.9). Examples were widespread in the US and Australia; including Los Angeles, Denver and Houston; and Canberra and Perth; but also include towns in the UK, such as Glasgow and Birmingham.

[11] Joel Garreau (1991) in *Edge City: Life on the New Frontier* lucidly describes the rapid growth of new (sub)urban centres in the US; home to corporate headquarters, fitness centres and shopping plazas. The new centres represent the move of jobs, the means of creating wealth and the very essence of urbanism, out to the suburbs, to where many people have been living for the last two generations. Is this the future for towns and cities in the UK (and Surrey)?

Figure 2.7: *The Traditional Walking City*

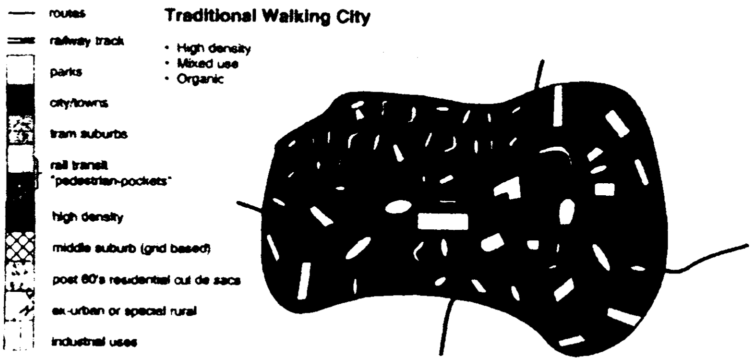


Figure 2.8: *The Public Transport City*

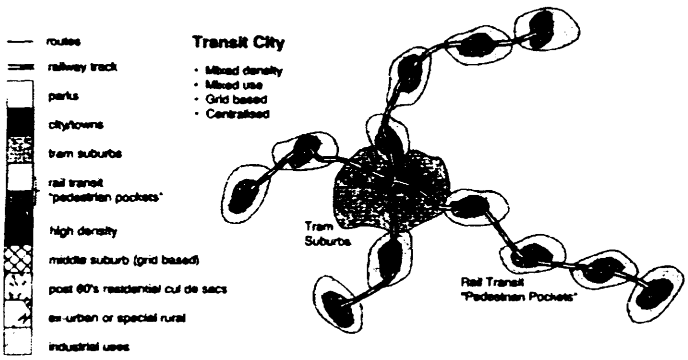
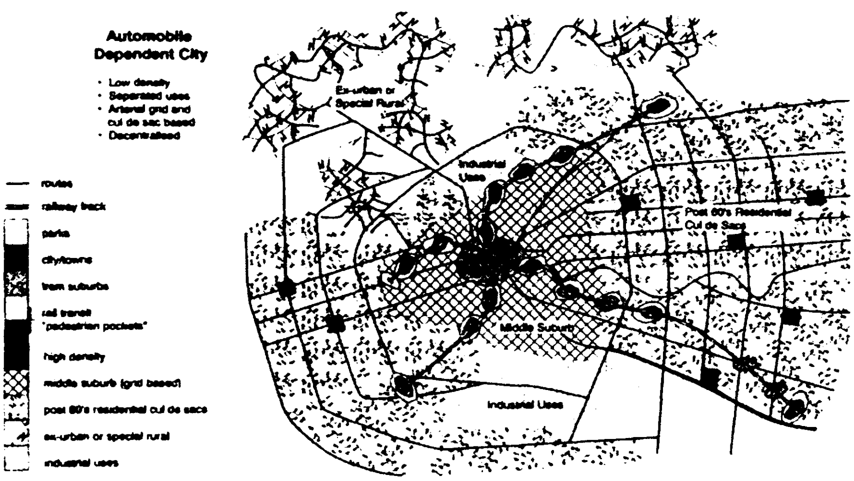


Figure 2.9: *The Car-Dependent City*



(Newman and Kenworthy, 1999)

Newman and Kenworthy obviously present a broad over-simplification of urban transport planning history. Most towns and cities include a hybrid of these typologies, and are served by a variety of transport systems, however it is instructive to study the broad stereotypes and develop general lessons from them.

2.4.2 A Developing Research Field

From 1989 onwards to the present day, a large amount of research has been carried out in the land use and transport interaction field. There are however a large number of remaining research questions. As noted previously, the focus of the research is in understanding the complexity of the land use, socio-economic and travel behaviour relationship and the influence of time.

Table 2.3 adds to the summary shown in Chapter 1 by highlighting a number of the existing research findings from the literature field, organised by topic and author. Against these, key research issues are presented - drawing on the research gaps – and which are developed into the particular research focus for this thesis. In using this structure of review it can be seen how the thesis topic has developed from a critical review of the literature field, and has been focused on a number of perceived literature gaps.

Table 2.3: *Transport and Land Use Interaction Field and the Thesis Focus*

Land Use and Socio-Economic Variables and Impact on Travel Behaviour	
Existing (Contradictory) Knowledge	**Key Research Issues and Thesis Focus**
Resident Population Density Much research follows the seminal Newman and Kenworthy (1989/1999) analysis. Dispute as to whether increasing density impacts on modal choice, travel distance and energy consumption. Various thoughts as to optimum urban form in reducing car travel: ranging from compact cities to 'decentralised concentration' and even low density suburban spread. Different definitions of density are used in various research studies. • Increasing densities reduces energy consumption by transport (Newman and Kenworthy, 1989a and 1989b) • There is no clear relationship between the proportion of car trips and population density in the USA. (Gordon et al, 1989a) • As densities increase, modal split moves towards greater use of rail and bus (Wood et al, 1994) • Compact cities may not necessarily be the answer to reducing energy consumption, due to effects of congestion, also decentralisation may reduce trip length (Breheny, 1995 and Gordon & Richardson, 1996) • 'Decentralised concentration' is the most efficient urban form in reducing car travel (Jenks et al, 1996) • On balance, compaction in various forms is likely to lead to some reductions in travel demand at the city and neighbourhood scales (Williams et al, 2000) • Density is the most important physical variable in determining transport energy consumption (Banister et al, 1997a) • Total distance travelled varies with density, up to a 20% variation (Banister, 1997a) • Higher densities may provide a necessary, but not sufficient condition for less travel (Owens, 1998) • As people move from big dense cities to small less dense towns they travel more by car, but the distances may be shorter (Hall, in Banister, 1998a) • Most academics found themselves in a remarkable - even unusual - degree of agreement: that development should be based on fairly small neighbourhood units, each combining homes and job opportunities and services ... clustered along public transport spines ... not to guarantee that everyone would minimise travel but to give them at least the opportunity if they wished (Hall, 1998)	• Impact of population and employment density at residence and workplace on mode choice, journey to work length and energy consumption. • Strength and significance of influence, range of difference by location and time.

Land Use and Socio-Economic Variables and Impact on Travel Behaviour	
Existing (Contradictory) Knowledge	**Key Research Issues and Thesis Focus**
Resident Population Size Perceived by many authors as a key determinant of travel, the general thesis being that the larger the settlement size, the shorter the trips and the greater number by public transport. Dispute as to whether population size impacts on modal choice, travel distance and energy consumption. • The largest settlements (>250,000 population) display lower travel distances and less by car (ECOTEC, 1993) • The most energy efficient settlement in terms of transport is one with a resident population size of 25-100k or 250k plus (Williams, 1998) • No correlation between urban population size and modal choice in the U.S.A. (Gordon et al, 1989a) • The search for the ultimate sustainable urban form perhaps now needs to be reorientated to the search for a number of sustainable urban forms which respond to a variety of existing settlement patterns and contexts (Jenks et al, 1996)	• Impact of population size at residence and workplace on mode choice, journey to work length and energy consumption. • Strength and significance of influence, range of difference by location and time.

Land Use and Socio-Economic Variables and Impact on Travel Behaviour	
Existing (Contradictory) Knowledge Jobs-housing balance and mix of use The conventional viewpoint in the literature is that the mix and balance of uses affects the physical separation of activities and, in part, determines travel demand. Dispute exists however as to the actual imact of mixed uses on modal choice, travel distance and energy consumption. • Widening jobs-housing balance in California is leading to lengthening commute trips (Cervero, 1985, 1989a and 1996a) • Diversity of services and facilities in close proximity reduces distance travelled, alters modal split and people are prepared to travel further for higher order services and facilities (Banister, 1996) • Much research advocates 'contained', compact, urban layouts with a mix of uses in close proximity, i.e. a move away from functional land use zoning (Williams, 2005)	**Key Research Issues and Thesis Focus** • Impact of jobs and housing balance on mode choice, journey to work length and energy consumption. • Strength and significance of influence, range of difference by location and time.

Land Use and Socio-Economic Variables and Impact on Travel Behaviour	
Existing (Contradictory) Knowledge Location Dispute in a scarce literature as to the impact of location – in terms of distance from urban centre, strategic transport network, public transport accessibility and influence of green belt - on modal choice, travel distance and energy consumption. • Location of new housing development outside existing urban areas, or close to strategic transport network, or as free-standing development increases travel and influences mode split (Headicar and Curtis, 1995 & 1997) • Location is an important determinant of energy consumption and car dependency (Banister et al, 1997) • Development close to existing urban areas reduces self-containment and access to non-car owners (Headicar, 1997)	**Key Research Issues and Thesis Focus** • Impact of distance from urban centre, strategic road network, public transport accessibility and influence of green belt on mode choice, journey to work length and energy consumption. • Strength and significance of influence, range of difference by location and time.

Land Use and Socio-Economic Variables and Impact on Travel Behaviour	
Existing (Contradictory) Knowledge Socio-Economic Dispute exists as to the impact of personal and household characteristics on modal choice, travel distance and energy consumption. There is no firm agreement as to whether personal and household characteristics are more important determinants of travel than land use characteristics. Little behavioural analysis of travel patterns and change over time. • Trip frequency increases with household size, income and car ownership (Hanson, 1982) • Travel distance, proportion of car journeys and transport energy consumption increases with car ownership (Naess, 1993a and 1996) • People with pro-car attitudes make more journeys by car and fewer journeys by public transport (Kitamura et al, 1997)	**Key Research Issues and Thesis Focus** • Impact of household income, house value, house type, number of bedrooms, tenure, children, sex of respondent, age group, marital status, occupation, car ownership, attitude to travel on mode choice, journey to work length and energy consumption. • Strength and significance of influence, range of difference by location and time.

Land Use and Socio-Economic Variables and Impact on Travel Behaviour	
Less Well Researched Areas	**Key Research Issues and Thesis Focus**
Temporal Dimension	
• Impact of time: some anecdotal evidence of 'co-location' of households and employment in California, USA. (Gordon and Richardson, 1997). But litlle systematic tracking of impact over time.	• Temporal effect: impact of change over time - i.e. when people move home and/or workplace - on travel behaviour in terms of mode choice, journey to work length and energy consumption. • Strength and significance of influence, range of difference by location and time.

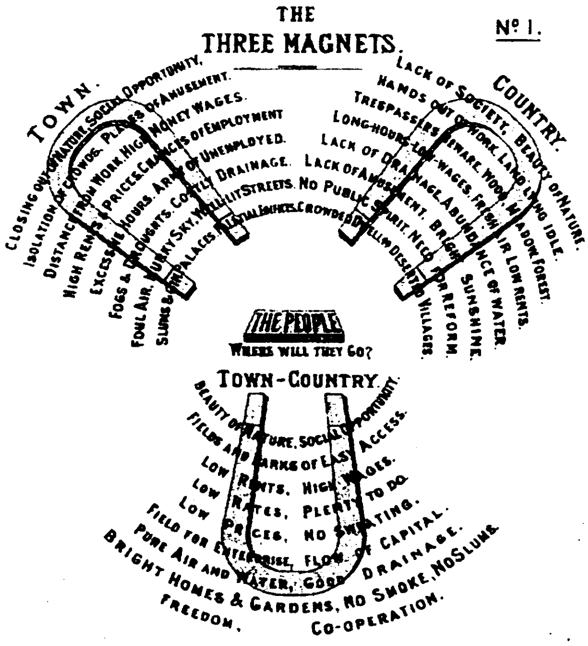
Land Use and Socio-Economic Variables and Impact on Travel Behaviour	
Less Well Researched Areas	**Key Research Issues and Thesis Focus**
Further Land Use Variables	
• Urban design quality: some anecdotal evidence in the USA (Kulash, 1990). Initial assessment in the UK (Marshall, 2004)	• Local and strategic urban design quality: impact of local neighbourhood design on travel behaviour in terms of mode choice, journey to work length and energy consumption influenced by type • Strength and significance of influence, range of difference by location and time.
Further Socio-Economic Variables	
• Dual-income households: little research evident.	• Dual-income households: assessment of how the choice of new housing location is influenced by the location of two workplaces, extent of 'excess travel' and reasons behind it, role of travel factor in choice of location of new home. • Strength and significance of influence, range of difference by location and time.
• Surrounding mobility levels: some anecdotal evidence in the USA. Little research known in the UK.	• Surrounding mobility levels: impact of the surrounding level of mobility on travel behaviour in terms of mode choice, journey to work length and energy consumption? • Strength and significance of influence, range of difference by location and time.

2.4.3 Bringing the Issues Together: Integrated Spatial Planning

A number of authors have been important in bringing the issues of population density, size and location, transport and community planning, etc. together and offering potential models for future urban development; Hall (1998) in *Sociable Cities* gives good commentary. Three different periods of history/innovative ideas in particular - although often documented - are worth highlighting here.

First, Howard's thoughts from 1898 are still incredibly relevant to the urban planning world today, and indeed to analysis in Surrey. His famous diagram of the three magnets (see Figure 2.10) neatly encapsulates the pros and cons of urban and rural life in Victorian Britain.

Figure 2.10: *The Three Magnets*



(Howard, 1898)

In developing his critique of both over crowded cities and rural depopulation, Howard wished to reverse the flow of migration by creating a third magnet, with all the opportunities of the town and all the qualities of the country. The way to achieve this was to create a new town in the middle of the countryside, beyond the influence of the big city. The Garden City ideal was born: a mixed use, medium density, fixed size development, with jobs, schools, shops, parks and countryside all within walking distance.

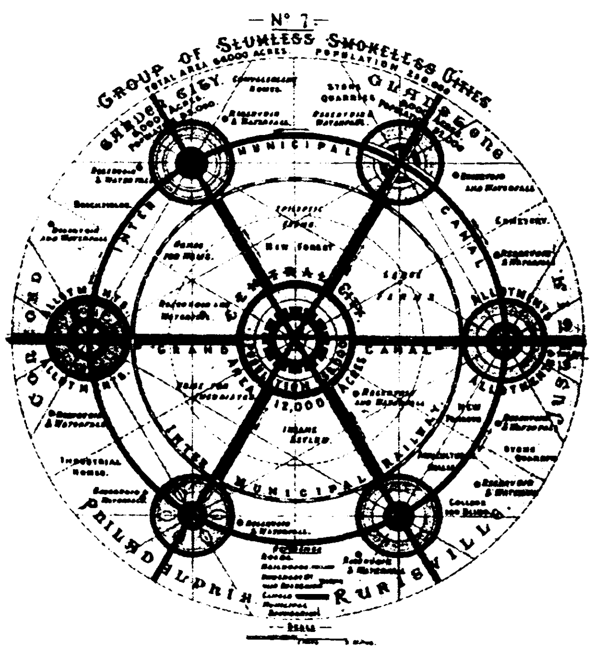
The Garden City concept developed into a network of linked settlements; a cluster of towns, linked by inter-town rail: a polycentric vision of the Social City.

The Garden City Association followed, as did a host of Garden Cities, Suburbs, Villages and eventually New Towns; from Letchworth to Hampstead, Welwyn, Stevenage and Milton Keynes, etc.[12] Howard's ideas were also exported abroad, with Garden Cities built in France, Germany, Russia and elsewhere.

Secondly, Hall (1988a) describes the experience of strategic planning in Copenhagen, Stockholm and Paris. The Copenhagen Finger Plan was produced in 1948, as a response to urban growth and growing congestion in the city. Future development was concentrated along selected suburban railway lines, with open space wedges preserved in between. In later revisions the plan was extended and further developed' with large satellite towns added along a number of the fingers.

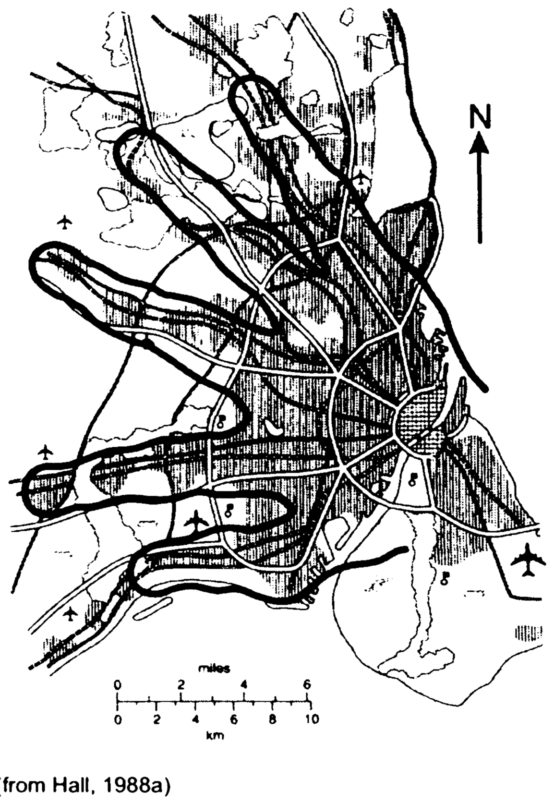
[12] Hebbert (1992) The British Garden City: Metamorphosis, in Ward (Ed) The Garden City: Past, Present and Future, also gives a good overview of the New Town experience.

Figure 2.11: *The Social City*



(Howard, 1898)

Figure 2.12: *The Copenhagen Finger Plan*



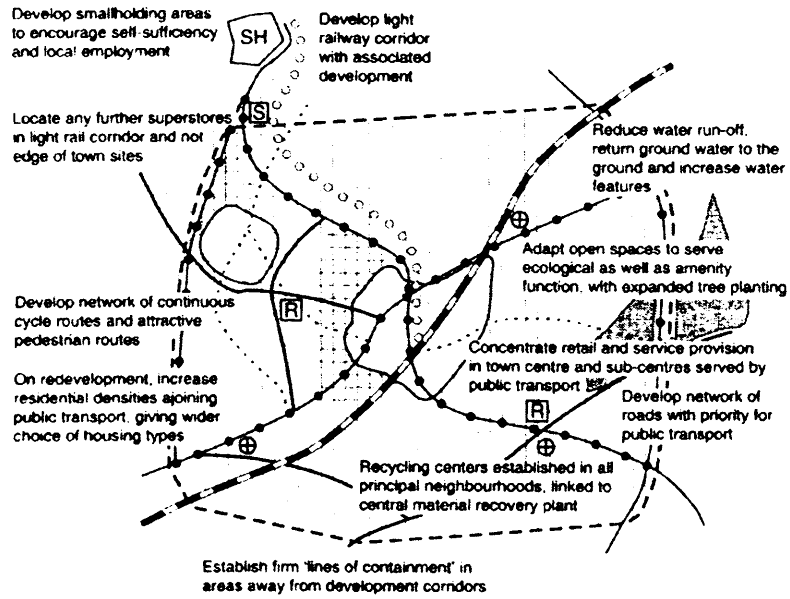
(from Hall, 1988a)

A similar exercise was carried out in Stockholm: the 1952 Markelius Plan established clusters of satellite towns – around Vällingby, Farsta and Skärholmen – centred along underground rail extensions, each with a pyramid of density; higher around the stations and shops, lower around the edge.

Also, in Paris, the 1965 Delouvrier Strategy developed five large new cities – Cergy-Pontoise, St-Quentin-En-Yvelines, Evry and Marne-La-Vallée - along two parallel axes, linked to the centre by a new express urban rail system and to each other by railways.

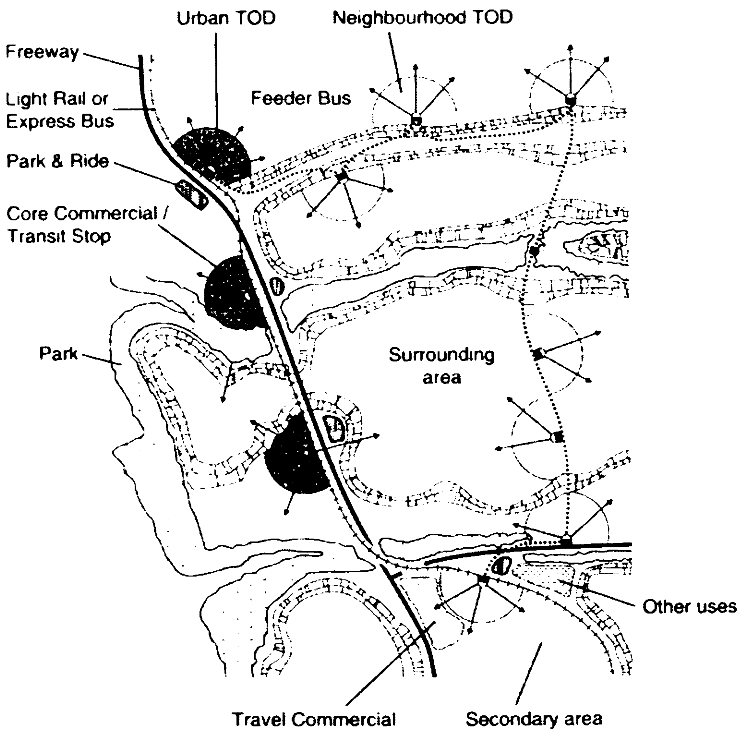
Finally, Breheny and Rookwood (1993) and Calthorpe (1993) offer not dissimilar models for future development based on sustainability principles. Breheny and Rookwood show the conceptual development of a mixed urban-rural area, with clusters of mixed use development, each of limited size, along public transport spines, with the intervening countryside preserved.

Figure 2.13: *Breheny and Rookwood's Sustainable Development*



Calthorpe proposes the concept of Transit-Oriented Development (TOD): walking scale suburban developments around public transit stops, clustering some job and service opportunities at the nodes, with high density single family housing built in traditional style terraces. TOD has been used to develop neighbourhoods in San Jose, California and is an underlying theme behind the General Plan for the state capital of Sacramento.

Figure 2.14: *Calthorpe's Transit-Oriented Development*



The interest in these ideas and concepts for this thesis - and for future urban planning in Surrey - is in their potential application, perhaps as modified concepts, based on the particular land use and transport relationships in the county. These ideas will thus be developed in the following thesis chapters.

2.5 Literature Review Conclusions

It is evident that the literature covering the land use and transport interaction field has developed rapidly since the late 1980s. The wider sustainability and urban planning debates, used as context to this thesis, have similarly developed expansively, but over a much longer time period.

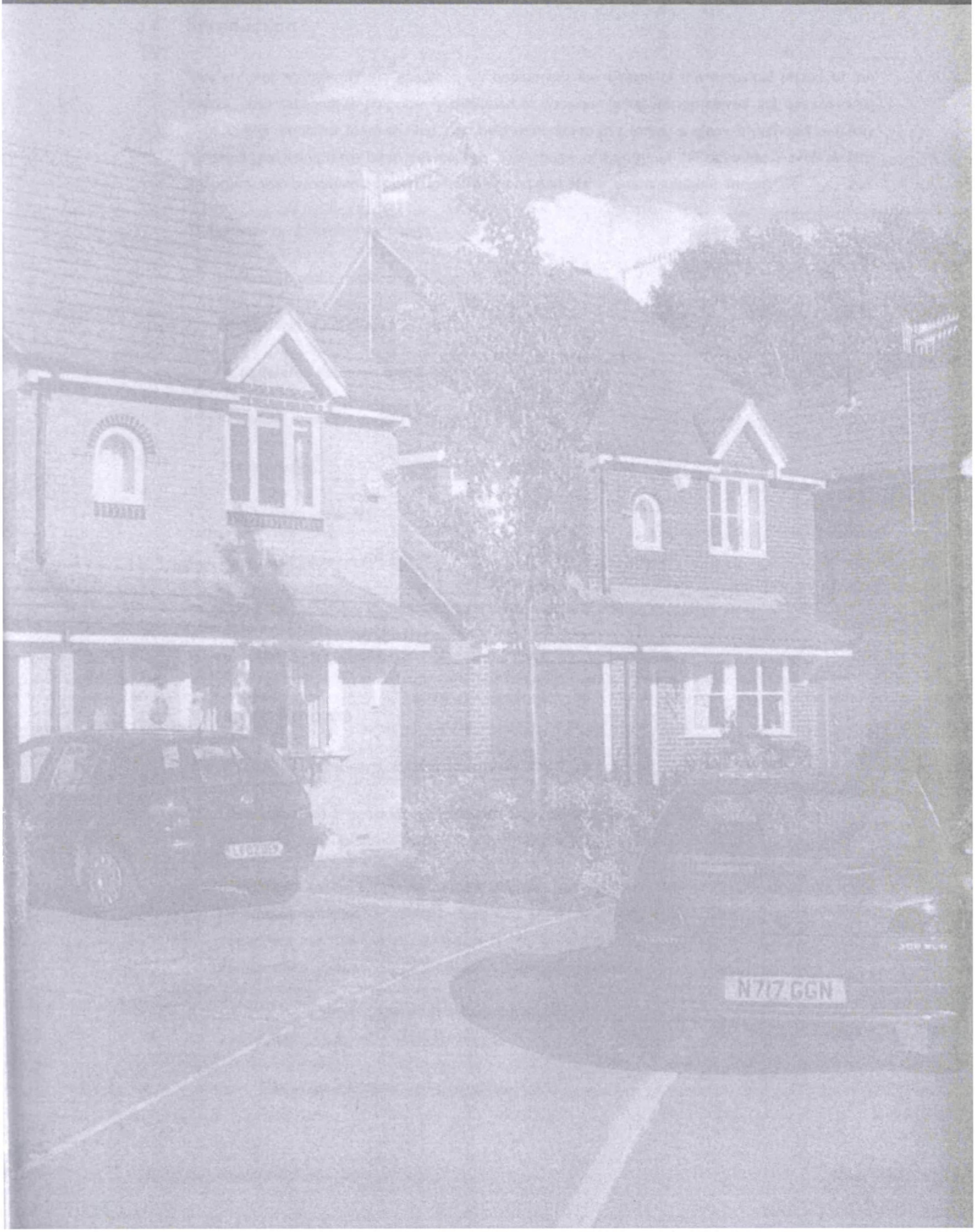
Much of the more interesting literature - taking the lead from Burgess and Mumford and others - is focused on understanding or developing a logic behind city development. This thesis extends this thinking in seeking to understand land use and travel behaviour. At times this logic is well hidden; detailed analysis however allows us to make some progress.

Many, indeed most, of the previous land use and transport interaction research studies have concentrated on the particular influence of individual land use variables, e.g. density or population size, on travel behaviour. They have been mostly concerned with bivariate relationships. Few have attempted to bring the individual land use themes together. Fewer still have considered land use and socio-economic (including attitudinal variables) and the temporal dimension in one co-ordinated research study. Hence the multi-disciplinary aspect has been missing from much of the research.

The key research gaps in the land use and transport interaction field thus are centred on a more rigorous understanding of the complexity of the land use, socio-economic and travel behaviour relationships, and in understanding the temporal dimension. This thesis is focused on these literature gaps - it particularly seeks to move on from the polarity in much of the interventionist and sceptic debate.

In terms of thesis structure, and how this is developed from the review of the literature, the next chapter (3) develops the research design and method, whilst the bulk of the empirical work is found in chapters 4, 5, 6 and 7. In turn they consider land use influences, socio-economic influences, the temporal effect and the interplay of factors. The synthesis (chapter 8) is particularly important in drawing the empirical thinking together and relating the key findings to previous work in the literature field.

03. Research Design and Method



3. Research Design and Method

3.1 Introduction

This chapter outlines all the assumptions concerning the design of the empirical phase of the thesis. The research is purposively designed to consider [what are perceived as] the research gaps in this particular reseach filed. To help understand this focus, a study hypothesis and key research questions have been developed. The choice of Surrey as the case study area is also important: with a location adjacent to London, and part of the 'urban/suburban fringe'.

The chapter is structured as follows:

- Discussion of the research process;
- Formulation of the study hypothesis;
- More detailed research questions;
- The study area (the county of Surrey);
- Survey design;
- Independent variables;
- Initial descriptive analysis;
- Dependent variables and assumptions concerned with energy consumption definitions;
- And, finally, key analytical techniques employed later in the thesis.

3.2 Research Process

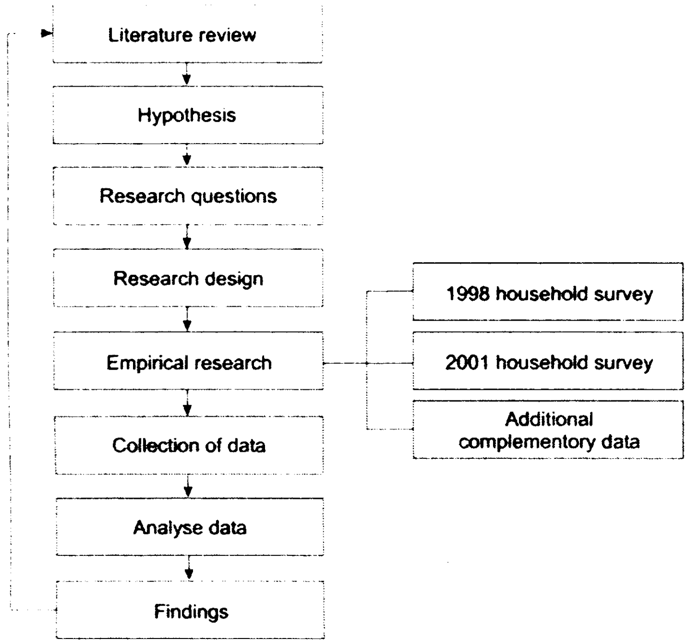
The structure of the research follows a common format, as outlined below and in Figure 3.1.

1. Literature review: provides an understanding of the literature field covering land use and transport interactions and identifying key research gaps;
2. Formulation of the study hypothesis: focused on the perceived research gaps; the study hypothesis provides a general statement of the factors relating to the behaviour of the dependent variable (which, in this case, is travel behaviour, measured in terms of energy consumption, journey length, journey time and mode share);
3. Development of a number of more detailed research questions exploring the research hypothesis, and for each of these, testing:
    - The null hypothesis: one of no difference (H_0);

- The alternative hypothesis: there is a difference (H_1)[13].

4. Research analysis, synthesis and conclusions: a final chapter outlining the main research findings relative to the literature field.

Figure 3.1: *The Research Process*



3.3 The Study Hypothesis

Figure 3.2 provides a 'mind map'[14] of the research structure, showing its placement in relation to earlier work and its focus and originality in terms of content. We can see that the context for the research is the history of urban planning and the sustainability agenda, whilst the focus of the analysis is aimed at gaining a greater understanding of the land use, socio-economic and transport behaviour relationship.

The study hypothesis is drawn directly from the literature review, particularly from an understanding of the key gaps in the literature. The research is structured to directly address these gaps.

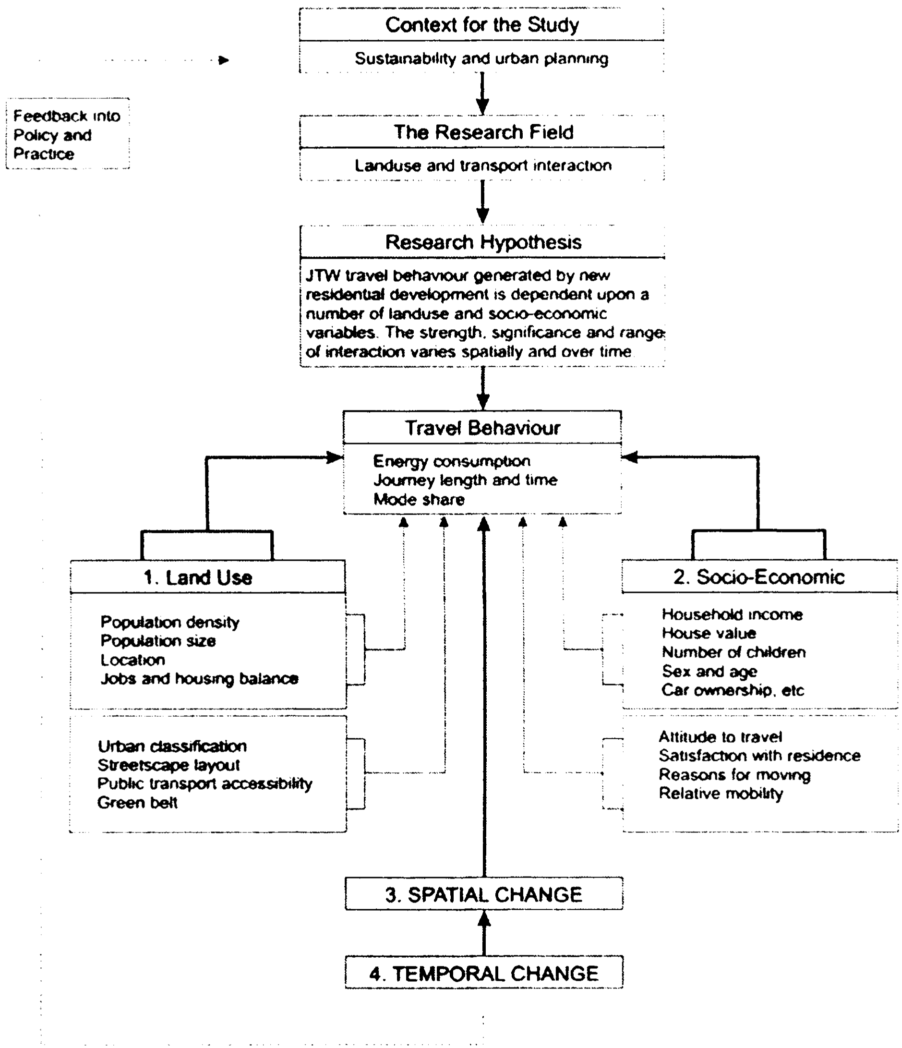
[13] The two hypotheses are statistical statements only. The null hypothesis is the testable expression of the working hypothesis/research question and, as usual, is one of 'no difference' between sample populations; whether we believe it or not is immaterial. It should be thought of as existing only within the setting of the statistical test within which it will be either accepted or rejected. If the null hypothesis is rejected then the alternative hypothesis must be accepted. This is the logical converse of the null hypothesis and asserts that statistically significant differences exist between the samples under study.

[14] For further discussion on mind mapping see Buzan (2002a); the basic premise being the use of diagrams which help to simplify complex ideas into easier to understand images.

The basic research hypothesis is that:

"Journey to work travel behaviour generated by new residential development is dependent upon a number of land use and socio-economic variables. The strength, significance and range of interaction vary spatially and over time."

Figure 3.2: *Research Structure*



As we have seen in Chapter 2, a number of authors provide good reviews of the literature concerning the impacts of land use form, particularly in terms of the relationship with travel behaviour. These include Newman and Kenworthy, Gordon and Richardson, Cervero, Banister, Hall, Stead, Owens, Headicar, Boarnet, Crane and Schwanen, amongst others. Owens (1998), for example, suggests that it is becoming more and more widely accepted that land use patterns influence travel demand, leading many to believe that changed planning policies could lead to a reduction in the need for movement. The latter inference has, not surprisingly, generated great interest, taken as an 'easy' and non-controversial way to reduce the ecological footprint of urban areas, and thus contribute to wider sustainability objectives. Hence the interest in, and attractiveness of, the land use and transport interaction field as a research topic.

This thesis takes this rich, varied and international literature as its context, and attempts to unravel the complexity of what is actually going on with the land use and transport relationship in the chosen study area of Surrey. In addition, the research considers the added temporal dimension and asks what happens to the land use and transport relationship over time?

3.4 Research Questions

The basic study hypothesis is explored by analysing a number of more detailed research questions. These are analysed in turn (in Chapters 4-7) and cover four broad areas, each considered in terms of their relationship with travel behaviour, as outlined below.

- **Land use influences**:
  - What is the influence of population density, population size, house location (proximity to London and the local road network) and jobs-housing balance on travel behaviour? These variables typically represent the previously "well-researched" areas in this field.
  - What is the influence of strategic urban classification and urban/rural distinctions, local neighbourhood street layout, public transport accessibility and resident location relative to the greenbelt on travel behaviour? These variables represent the less-frequently "under-researched" areas.
- **Socio-economic influences**:
  - What is the influence of household income, car ownership, children per household, respondent sex and age, etc on travel behaviour? Again, these represent the previously 'well-researched" areas.
  - What is the influence of attitude to travel, attitude to house location, relative levels of mobility and dual-income households on travel behaviour? Again, these represent the less-frequently, "under-researched" areas.
- **Temporal effects**: What impact does time have on the land use, socio-economic and travel relationship and how is travel behaviour is modified over time?
- **The interplay of factors**: What multi-variate relationships are evident in land use and transport interactions?

Critically, the thesis covers a broad range of issues, ranging from the strategic to local scales, as shown in Figure 3.3.

Figure 3.3: *Research Coverage*

Clustering: concentration and density of development

Structure: development type, size and shape

Location: proximity to existing towns, infrastructure

Landuse mix: jobs and housing balance, scale of local facilities

Layout and design: neighbourhood type

STRATEGIC

Global

National

Regional

Sub-regional

Country

District

Town

Neighbourhood

Individual

LOCAL

Household type: Income, house value and car ownership

Individual characteristics: sex and age and number of children

Behavioural: Attitude to travel, satisfaction with residence, reasons for move

(Based on Stead, 1999)

There are a number of key themes that run throughout the analysis. For example:

- The thesis seeks to develop a better understanding of what, in tabloid style, might be called the Newman and Kenworthy versus Gordon and Richardson nexus: - essentially, can land use planning play a role in reducing the impact of travel behaviour?

- Added to this we have the influence of Harvey and Castells: the impact of spatio-temporality – what happens over time? Has co-location of homes and jobs occurred and, if so, of what type and to whom?

- And finally, the influence of scale: what might be called the Headicar versus Banister nexus – are changes at the individual level masked by looking at aggregate-level change?

Within these broad themes there are a number of key issues which, again, are analysed throughout the thesis. These are outlined as follows:

- What is our current understanding of the land use and transport relationship? What about wider land use impacts that have traditionally not been considered as part of the picture?

- What is our current understanding of the socio-economic and transport relationship? What about wider socio-economic impacts?

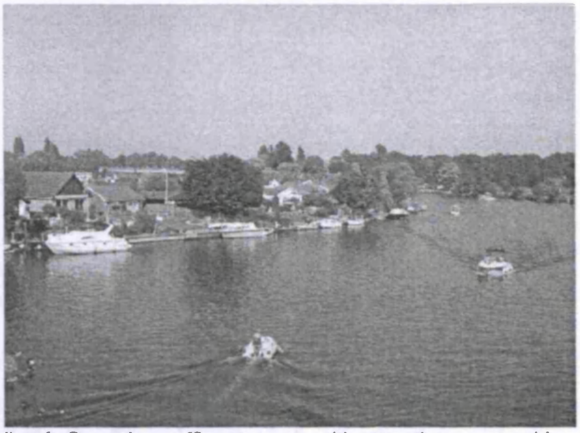
- What happens to travel behaviour over time? Have homes and jobs co-located? Have commuting distance, time and energy consumption decreased? Has car dependency decreased?

- How do we bring the land use, socio-economic and transport relationships together? Which variables play more of an influence than others? How do we quantify this? What can we learn from inferential analysis?

These key themes and issues are directly addressed in Chapter 8.

3.5 The Study Laboratory: the County of Surrey

Burgess (1925) called Chicago his "living laboratory" and this thesis uses the county of Surrey as its very own living study laboratory. Located in the southeast of the UK, the county is found on the edge and to the southwest of the London conurbation. The county is strongly influenced by London and has a high proportion of commuters travelling into (and out of) Inner and Outer London.



'Leafy Surrey': an affluent county with attractive countryside, a sought after place to live

Much of the work carried out associated with the urban renaissance, integrated transport and planning and new urban design agenda has focused on cities, for example, either London or the core cities (Liverpool, Manchester, Leeds, Bimingham, etc.). There has been little research carried out in suburban locations or London-fringe locations. There is a distinct need therefore for research to include consideration of the whole [wider] labour catchment areas, commuting regions and city-regions. Our understanding is poor in these locations, hence the choice of Surrey as a case study area.

The major towns in Surrey are Guildford (with a population of over 65,000) and Woking (56,000), and Epsom, Camberley, Ewell, Farnham and Redhill (all over 30,000)[15]. The main transport links are the M25, M3, M23 and A3, and a series of (mainly radial) rail lines directed northeast towards London. The county of Surrey is shown in Figure 3.4.

Possibly because there is no major planning school within Surrey, the county has not been studied, in urban planning academia terms, to the extent of others, such as Oxfordshire, or London itself, or California in the USA. Hopefully this makes for ever-more interesting reading. The relationship with London in terms of commuting is also important to understand. The county is also one of the most affluent areas in the UK, with high income levels, car ownership rates and personal mobility patterns. Hence, in terms of reducing current high car dependent lifestyles, Surrey is potentially one of the most difficult areas to work in. Key demographic indicators are as outlined in Table 3.1.

[15] Source: 2001 Census, see www.ons.gov.uk or www.surreycc.gov.uk

Figure 3.4: *The County of Surrey*

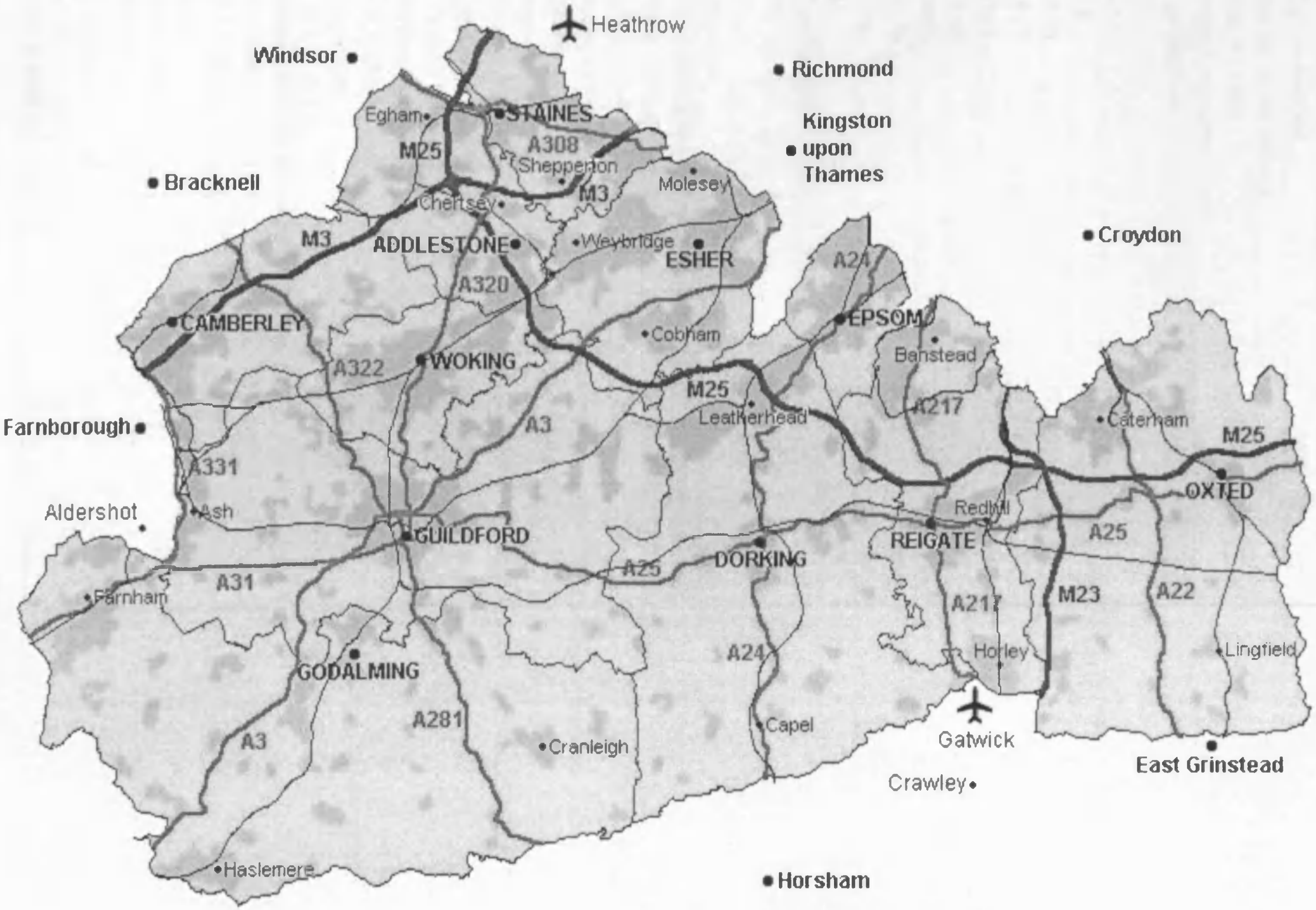
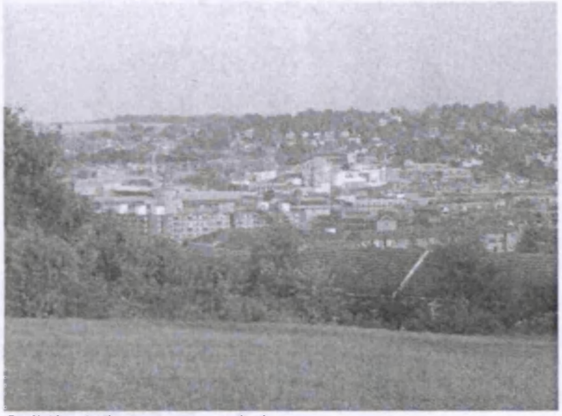


Table 3.1: *Surrey Census Profile (2001)*[16]

Demographic Data		
Population		
Total population	1,059,015	
Males	516,525	
Females	542,490	
In households	1,032,781	
In communal establishments	26,234	
Change in total population since 1991	3.5%	
Total households	433,176	
Average household size	2.38	
Area of County	167,004 ha	
Average population density	6.3	
Age Structure	**Number**	**Percent**
0-4	62,849	5.9%
5-7	39,121	3.7%
8-9	26,477	2.5%
10-15	77,799	7.3%
16-17	24,618	2.3%
18-24	79,041	7.5%
25-44	311,289	29.4%
45-64	265,656	25.1%
65-74	88,022	8.3%
75-84	60,247	5.7%
85+	23,896	2.3%
Country of Birth		
UK	946,400	89.4%
EU	36,416	3.4%
Elsewhere	76,199	7.2%
Economic Position (of Population Aged 16-74)		
Males economically active	301,485	79.4%
Employed full time	212,382	70.4%
Employed part time	11,471	3.8%
Self employed	60,524	20.1%
Unemployed	7,741	2.6%
Full time student	9,367	3.1%
Females economically active	246,150	63.3%
Employed full time	128,835	52.3%
Employed part time	77,399	31.4%
Self employed	23,885	9.7%
Unemployed	5,581	2.3%
Full time student	10,450	4.2%
Travel to Work (main part of journey to work)		
Car (driver or passenger)	343,708	64.5%
Rail (including Underground or tram)	56,635	10.6%
Bus	12,242	2.3%
Motor cycle	6,269	1.2%
Bicycle	11,900	2.2%
Walking	42,477	8.0%
Other	2,445	0.5%
Work at home	57,143	10.7%

[16] For further details see www.surreycc.gov.uk

In Figure 3.5 we can see how the main urban areas have developed in Surrey over the last century; the impact on travel behaviour patterns has been enormous, but is little understood. Clearly future growth is likely to have a great impact on travel behaviour patterns in and around the county.



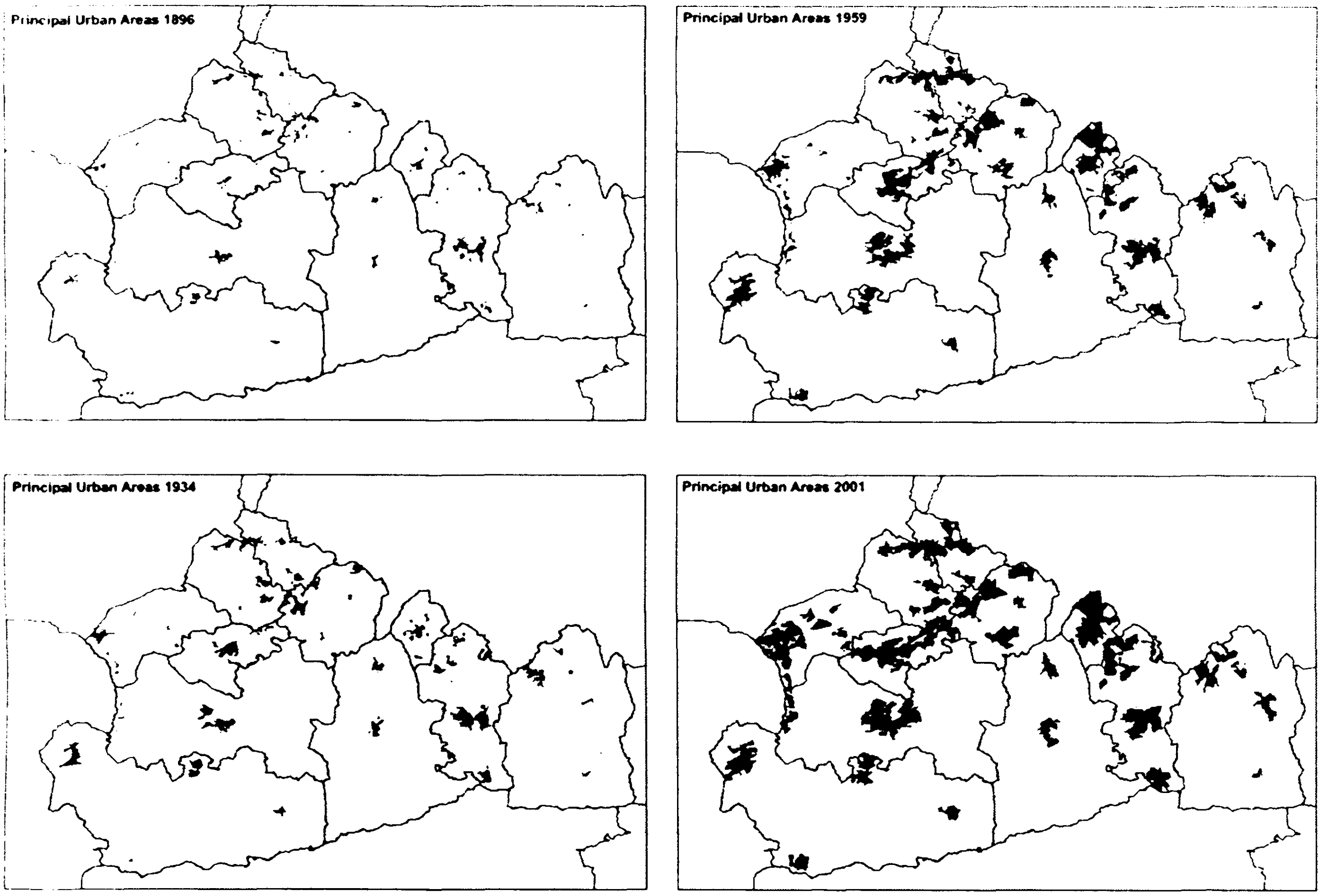
Guildford: the county capital

Woking: the second largest town

The housing stock in Surrey includes many large residences; prices are often beyond average incomes

The county of Surrey is well known for its beautiful countryside and quality of life

Figure 3.5: *Urban Development in Surrey 1896-2001*[17]



3.6 Survey Design

The main phase of empirical research used two household surveys of new household occupiers in Surrey. Two rounds of surveys were sent out: the first to occupiers of new households in 1998; and a follow up, to the same households, in 2001. Addresses added to the Council Tax Register in 1998 were used as the database for new household addresses.

Surrey County Council sent out the first household survey as part of their Structure Plan monitoring programme, independent of the research for this thesis, but made the raw data available for analysis. The second survey was sent out directly by the author for use in this thesis, with postage and paper kindly funded by Surrey County Council. Copies of the surveys are found in the Annex.

Response rates were good for both postal surveys at 54% (in 1998) and 39% (in 2001); both included promptings with 'reminders to reply' letters and also a £50 prize draw; the latter again funded by Surrey County Council[18].

[17] Source: Surrey County Council (2004). Urban areas as defined in Local Plans and historical mapping.

[18] Jim Storrar from the Environment Department, Surrey County Council was the (more than) extremely helpful contact on the planning side.

Surrey County Council also provided transport modelling data from the County Transport Model[19]. Journey lengths and times were estimated using household origins and workplace destinations (both postcode based and using multi-modal journeys, and through the network rather than crow-fly distances).

The problem of attrition in temporal comparisons is dealt with in detail in Chapter 6. In essence, to avoid the potential difficulties with attrition, for example where changes in behaviour may be due to the loss of survey respondents from one survey to another (rather than changes in independent variables), all temporal comparisons only use matched pair survey responedents, meaning that there is a smaller sample considered, but eradicating any attrition issues.

3.7 Independent Variables

The independent variables used in the analysis, and the associated measurement assumptions, are as shown below.

Table 3.2: *Independent Variables*

Independent Variable	Measurement
Land use characteristics	
Population density	Resident population density - usually resident persons/hectare by ward (1998 SCC data, 2001 Census data) Employment population density - workplace based jobs/hectare by ward (1998 SCC data, 2001 Census data)
Population size	Usually resident persons by key town (Guildford, Woking, Epsom, Camberley, Ewell, Farnham and Redhill); other 33 towns in Surrey; or other rural (1998 SCC data, 2001 Census data)
House location (proximity to London)	Distance from Centre Point, km (corner of Tottenham Court Road and Oxford Street, London)
House location (proximity to the strategic road network)	Household location within 3km buffer zone of M25, M3, A3, A31
Jobs-housing balance	(Jobs (workplace based, households x persons per household ward jobs average) x 0.66 average workforce for Surrey)/households (1998 SCC data, 2001 Census data)
House location strategic urban classification (town centre, rest of urban area, rural)	Household location relative to town centre, rest of urban area, rural classification (based on local development plan definition)
Local neighbourhood streetscape design	Household location and local street network design: (1) Neo-traditional grid; (2) cul-de-sac (3 or more routes from one access) and near to a village or town centre (a Post Office or rail station within a 800m walk); or (3) cul-de-sac remote (a Post Office or rail station beyond a 800m walk)
Public transport accessibility	Household location relative to public transport accessibility (bus and rail) to 28 major town centres in Surrey (PTAM software used)
House location (relative to the green belt)	Household location relative to urban, green belt, countryside beyond the green belt classification (based on local development plan definition)
Socio-economic characteristics	
House tenure	Owner occupied outright, owner occupied with mortgage, other (employer owned, private rented, public rented, shared ownership). (New Household Occupier Survey, NHOS, response 1998 and 2001)

[19] Steve Howard, similarly so in providing transport modelling data for use in the thesis analysis.

House type	Detached, semi-detached, terraced , purpose built flat, other (converted flat, detached bungalow, semi-detached bungalow, terraced bungalow). (New Household Occupier Survey, NHOS, response 1998 and 2001)
House size	Number of bedrooms. (New Household Occupier Survey, NHOS, response 1998 and 2001)
Number of children	(New Household Occupier Survey, NHOS, response 1998 and 2001)
Car availability	2001 data only (NHOS response 2001)
Company car ownership	2001 data only (NHOS response 2001)
Household income	2001 data only (NHOS response 2001)
House value	2001 data only (NHOS response 2001)
Respondent sex	(New Household Occupier Survey, NHOS, response 1998 and 2001)
Respondent age	(New Household Occupier Survey, NHOS, response 1998 and 2001)
Marital status	Married/partner, divorced/separated, single, widowed(New Household Occupier Survey, NHOS, response 1998 and 2001)
Occupation	Employed full time, employed part time, self employed (New Household Occupier Survey, NHOS, response 1998 and 2001)
Qualification	Highest level of qualification – degree or higher, A level, O level, other. 2001 data only (NHOS response 2001)
Attitude to travel	Attitude to the environment
	Attitude to public transport
	Attitude to suburban living
	Attitude to car mobility
	Attitude to time pressure
	Attitude to urban village living
	Attitude to traffic demand management
	Attitude to work
	All 2001 data only (NHOS response 2001)
Attitude to house location	Satisfaction with area of residence
	Preferred home location
	Preferred type of home
	Preferred open space
	Preferred car parking
	All 2001 data only (NHOS response 2001)
Reason for moving/choosing new location	(New Household Occupier Survey, NHOS, response 1998 and 2001)
Relative levels of mobility	Average journey to work length by ward (2001 Census data)
	Average journey to work mode share by ward (2001 Census data)
Dual-income households	Single, dual, multiple (New Household Occupier Survey, NHOS, response 1998 and 2001)
Stretch commuting	>40km commute (New Household Occupier Survey, NHOS, response 1998 and 2001)
Other Definitions	
Stayers disaggregation	People who occupied a new household in September 1998 and who still lived in the same household in September 2001
Outmovers disaggregation	People who occupied a new household in September 1998, but moved out before September 2001
Inmovers disaggregation	People who lived elsewhere in September 1998, but moved into a new household before September 2001

3.8 Descriptive Analysis of the Data

Key descriptive data from the new household occupiers survey (NHOS) is shown in Table 3.3.

Table 3.3: *The New Household Occupiers Surveys*

NHOS	1998	2001
Number of surveys	2,920	1,568
Response rate	54%	39%
Total households returned	1,568	607
Total adult respondents	2,865	1,103
Total working respondents	1,916	698

Date of Move	Frequency	Percent
Pre-Sept 1998	428	71%
Post-Sept 1998	172	28%
Not stated	7	1%
Total	607	100%

Category	Surrey NHOS				Census 2001
	1998		2001		
	Frequency	Percent	Frequency	Percent	Percent
Sex					
Female	1,470	51%	498	50%	49%
Male	1,369	48%	477	49%	51%
Not stated	26	1%	128	1%	0%
Total	2,865	100%	1,103	100%	100%
Age					
0-16	893	24%	345	24%	22%
17-24	237	6%	69	5%	8%
25-44	1,531	41%	510	35%	30%
45-retirement	678	18%	310	21%	25%
Over retirement	402	11%	214	15%	16%
Not stated	17	0%	0	0%	0%
Total (discounting under 16s)	2,865	76%	1,103	76%	78%
Total	3,758	100%	1,448	100%	100%
Occupation					
Employed: full time	1,499	52%	511	46%	44%
Retired	443	15%	227	21%	16%
Looking after home or family	307	11%	119	11%	10%
Self employed	222	8%	76	7%	11%
Employed: part time	195	7%	111	10%	12%
Student	105	4%	36	3%	-
Unemployed	43	2%	12	1%	2%
Other	51	2%	5	0%	-
Not stated	0	0%	6	1%	-
Mode Share (Journey to Work)					
Car	1,303	72%	404	68%	65%
Rail	300	17%	98	16%	11%
Total	2,865	100%	1,103	100%	100%

The NHOS data differs marginally from Surrey-wide data (2001 Census) in that the cohorts '25-44 age group', 'employed full time', 'retired', and 'car drivers' are slightly over represented; whilst the cohorts '45-retirement' and 'self-employed' are slightly under represented. The sample differences are small, hence it appears that transferability of the NHOS results to Surrey as a whole would be valid. However an important point: the analysis that follows is not based on inferring that behaviour in the NHOS reflects that of Surrey as a whole. The interpretation is simply based on patterns and trends found within the new household occupiers in Surrey. Hence there are no transferability difficulties.

The use of household surveys is similar to that carried out by Curtis and Headicar (1994), however differs in that the households are drawn from across Surrey (rather than from selected housing estates); more data is available in terms of land use and socio-economic characteristics; and the use of two surveys of the same households at different times allows for time-series analysis.

The three-year time span between the two surveys (the surveys were carried out in 1998 and 2001) allows for some analysis of trends over time, within the confines of a limited research timeframe allowed in a PhD, and using a limited matched pair sample to avoid attrition problems. Further analysis of change over time may be interesting as later, follow-up research (for example, as a comparator, the average frequency of moves within Surrey is higher than 3 years).

3.9 The Key Travel Behaviour Dependent Variable: Energy Consumption

The main hypothesis and key research questions involve the testing of land use, economic, social or attitudinal independent variables against dependent journey to work travel behaviour indicators. The journey to work is used rather than all trip types to highlight the strong relationship between housing and employment location, the change over time (with changed residences and workplaces), and also was a result of what data was most easily available from new household survey analysis. Journey to work travel behaviour is represented in four ways: journey length, time and mode and energy consumption.

Table 3.4: *Dependent Variables*

Independent Variable	Measurement
Energy Consumption	MJ/km
Journey Length	Km (through the network, measured using the Surrey County Council transportation model)
Journey Time	Mins (through the network, measured using the Surrey County Council transportation model)
Mode Share	% Car and Public Transport Mode Share

Energy consumption measures are useful in that they combine the four main characteristics of travel (mode, distance, frequency and occupancy) to give a *composite* measure of travel. If any one of these four variables changes, then this is reflected in a change in energy consumption. In this thesis we use the methodology as developed by Banister et al[20] to define energy consumption.

[20] Source: Banister, D., Watson, S., Wood, C. (1997) Sustainable Cities: Transport, Energy and Urban Form, in *Environment and Planning B: Planning and Design*. The working method to estimate energy consumption has progressed over the years. The above is based on Banister et al, 1994; which itself was adapted from ACEC, 1976; Howard, 1990; Hughes, 1993; and Wood et al, 1994. The methodology used is also similar to that developed at the Norwegian Institute of Urban and Regional Research (see for example, Naess 1993; and Naess et al, 1996).

Average energy consumption data for different modes of transport are calculated from national data (as shown in Table 3.5).

Table 3.5: *Energy Consumption by Mode*[21]

Mode	Seats or Spaces	Energy Consumption, MJ per:			
		vehicle km	seat km	passenger km	
Rail:					
Inter City electric	564	316	0.56	1.4	
Inter City diesel	490	210	0.43	1.1	
Suburban electric					
25kV AC	300	132	0.44	2.0	
750 V DC	386	111	0.29	1.3	
Suburban diesel	146	73.6	0.50	2.3	
Average 'BR'	377	168	0.54	1.6	
London Underground	555	141	0.25	1.7	
Average	407	164	0.41	1.6	
Light Rail	265	79.8	0.3	0.9	1.2
Bus:					
Double decker	74	18.5	0.25	0.75	1.25
Single decker	49	17.5	0.36	1.07	1.79
Average 'big bus'	62	18.0	0.29	0.87	1.45
Minibus	20	8.0	0.4	1.2	1.2
Average bus	48	14.7	0.34	0.92	1.53
Express coach	46	15.0	0.33	0.98	1.63
Car:					
Small petrol (1.1L)	4	2.6	0.65	1.5	
Large petrol (2.9L)	4	5.3	1.33	3.0	
Small diesel (1.8L)	4	2.3	0.58	1.3	
Large diesel (2.5L)	4	3.3	0.83	1.9	
Average	4	3.7	0.92	2.1	
Other:					
Motorcycle	2	1.9	0.95	1.7	
Moped	1	1.5	1.5	1.5	
Average	1.3	1.6	1.33	1.6	

NB. The modal primary energy consumption figures are measured in megajoules (MJ) and they include energy use in maintenance. The capacity figures for London Underground and light rail refer to passenger spaces rather than seats. Average figures for cars, motorcycles and mopeds are weighted according to national (GB) fleet sizes (DoT, 1993).

The above data is based on all-day occupancy figures as follows:

- Inter City electric and diesel: 40%
- Suburban: 22%
- London Underground: 15%
- Light rail: 33% and 25% (hence the two passenger km energy consumption options above)
- Bus: 33% and 20% (hence the two passenger km energy consumption options above)
- Car occupancy: a weighted average of 1.76 (work = 1.2 and non-work = 1.85)

[21] Stead (1999) gives further details as to the variability in energy consumption by mode due to factors such as vehicle age, fuel type, engine temperature, vehicle speed, engine size and driving style etc.

- Occupancy for motorcycle is 1.11 and for moped is 1.00
- 'BR' refers to train services formerly run by British Rail

Occupancy assumptions are modified within the analysis in this thesis to reflect that the commute trip is being considered. Occupancy figures therefore more fully reflect commuting behaviour. Summary data used for Surrey is as follows:

- Car – occupancy of 1.2 (source: AM peak data, Surrey County Council, Transportation Model, 2001). Energy consumption factor = 2.87 MJ/km
- Train – loading factor of 90% (source: AM peak data, Strategic Rail Authority, Network Rail, Route Utilisation Strategy, 2006). Energy consumption = 0.52 MJ/km
- Bus – loading factor of 80% (source: AM peak data, Surrey County Council, Transportation Model, 2001). Energy consumption = 0.38 MJ/km
- Walk and cycle – loading factor of 1. Energy consumption = 0 MJ/km

This focus on commuting trips, and in particular the occupancy loading, means that there is a greater differentiation between travel by private car and train, bus, walking and cycling. Travel by car becomes more energy consuming. Analysis for all trips would use different occupancy assumptions, hence there would be less differentiation between car travel and other modes (the car would have a higher occupancy assumption, and rail and bus less in terms of loading).

A further caveat to the working method should be noted here: the estimation of energy consumption used in this thesis is based on 1993/94 data; this was the best published data available when the empirical phase of the research started in 1999/2000.

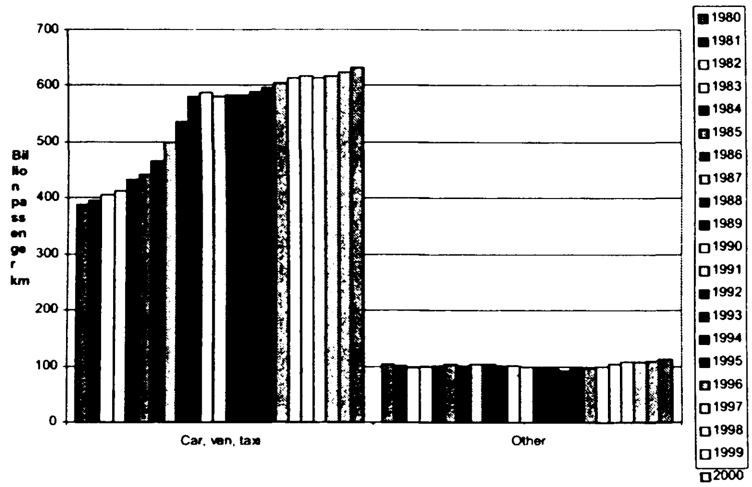
It is now possible to update the figures using Transport Statistics Great Britain (DfT, 2004a) data. Table 3.4 shows the main changes for the car since the early 1990s. Passenger km by car have increased by 9% (see Figure 3.6) and vehicle occupancy has fallen by 8%, both of these have led to increased energy consumption levels. This has been offset by improved vehicle and fuel efficiency and a switch to diesel usage (and a very minimal use of hybrid vehicles), these trends have led in the opposite direction - to reduced energy consumption. Therefore in aggregate, although total energy consumption levels are rising, energy consumption by car by distance travelled (MJ/km) has become more efficient: a *9% improvement* in 10 years. The annex provides further details as to the working method used to calculate energy consumption in MJ/km.

Hence the underlying rationale behind the estimation of energy consumption has not changed markedly between 1992-2002. A further area of research building on this thesis however would be to run the empirical analysis used here using updated energy consumption figures. This hasn't been possible in this thesis due to time constraints.

Table 3.6: *Recent Changes in UK Energy Consumption*

	1992	2002	% Change
Energy Consumption (Oil Equivalent)			
Road transport petroleum (Mtoe)	39.4	42.0	+6.6%
Petrol	27.2	22.2	-18.1%
Diesel	12.2	19.7	+61.6%
Energy Consumption (GJ/Tonne)			
Road transport petrol (GJ/tonne petrol)	1,287.3	1,053.9	-18.1%
Road transport diesel (GJ/tonne diesel)	558.8	903.0	+61.6%
Energy Consumption by Mode (GJ/tonne)			
% of petrol by car	1,158.6	1,001.2	-13.6%
% of diesel by car	55.9	198.7	+255.5%
Sub-total by car	1,214.5	1,199.8	-1.2%
Total Car Stock (million)	20.9	28.5	+36.4%
petrol	17.6	23.9	+35.8%
diesel	2.7	3.7	+37.0%
other	0.6	0.9	+50%
EC (MJ/km)			
Car	**2.1**	**1.9**	**-0.09**

Figure 3.6: *Increase in Passenger Km by Car*



(DfT, Transport Statistics GB, 2004a)

3.10 Analytical Techniques

A number of research techniques are employed in the research analysis. These include descriptive analysis, cross tabulations, bar charts, scatter graphs, box plots, correlations, multiple regression analysis and comparisons with other research findings.

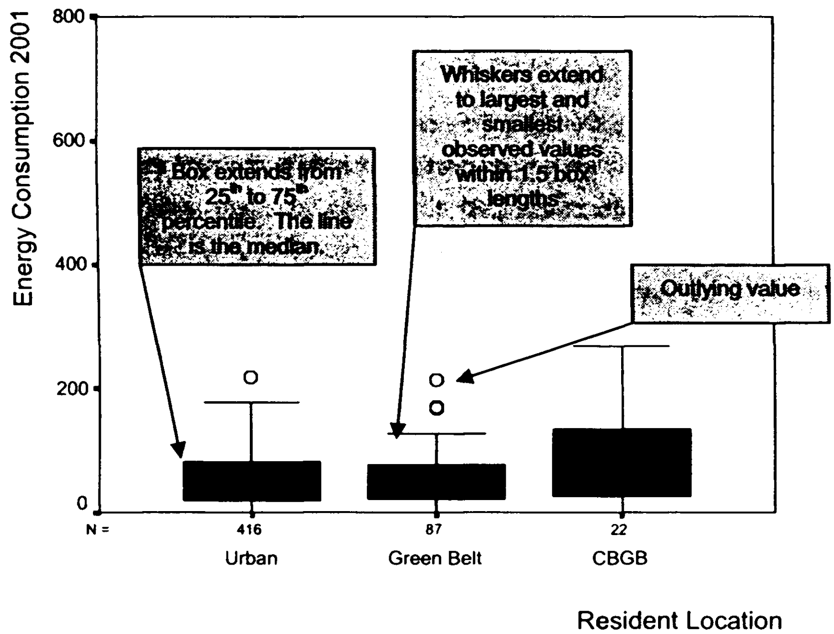
Several key sources proved invaluable in explaining the use of statistical techniques. These include Shaw and Wheeler (1998), and Bryman and Cramer (1999); and in particular two online statistics websites: http://www2.chass.ncsu.edu/garson/pa765/regress.htm (*PA 765 Statnotes: An Online Textbook*, Garson, 2004) and http://www.statsoft.com/textbook/stathome.html.

The techniques used most frequently in the later analyses are box plots, correlations and multiple regression analysis. These are described in brief below, again mostly drawing from Garson (2004).

Boxplots

The boxplot helps in the visualisation of the distribution of a variable. This simultaneously displays the median, the interquartile range, and the smallest and largest values for a group. Figure 3.7 shows a typical boxplot output.

Figure 3.7: *Boxplot Analysis Example*



- The lower boundary of the box represents the 25th percentile. The upper boundary represents the 75th percentile[22]. The vertical length of the box represents the interquartile range. 50% of all cases have values in the box. The line inside the box represents the median.

- There are two categories of cases with outlying values. Cases with values between 1.5 and 3 box lengths from the upper or lower edge of the box are called outliers and are designated with (0). Cases with values more than 3 box lengths from the upper or lower edge of the box are called extreme values; these are designated with a (*). Lines are drawn from the edges of the box to the largest and smallest values that are outside the box but within 1.5 box lengths.

[22] The percentile values known as Tukey's hinges are used to construct the box. For more information on the use of boxplots, see Norusis (1998) *Guide to SPSS Data Analysis.*

Correlation Analysis

Correlation is a bivariate measure of association (strength) of the relationship between two variables. It varies from 0 (a random relationship) to 1 (a perfect linear relationship: taking the form "The more the x, the more the y, and vice versa") or -1 (a perfect negative linear relationship, taking the form "The more the x, the less the y, and vice versa"). See Garson (2004) for more detailed discussion.

Pearson's R is the usual measure of correlation, sometimes called the product-moment correlation. It is usually reported in terms of its square (R^2), interpreted as percent of variance explained. For example, if R^2 is 0.25, then the independent variable is said to explain 25% of the variance in the dependent variable.

A number of techniques are available. Within the analysis in this thesis, Pearson's product moment correlation[23] is used to examine interval data, and Kendall's tau[24] for ordinal variables. Chi square[25] is used for nominal data.

It should be noted that there are common pitfalls in using correlation. Correlation is symmetrical, therefore does not provide evidence of which way causation flows. If other variables also cause the dependent variable, then any covariance they share with the given independent variable in a correlation will be falsely attributed to that independent. Also, to the extent that there is a non-linear relationship between the two variables being correlated, correlation will understate the relationship. Correlation will also be attenuated to the extent there is measurement error, including use of sub-interval data or artificial truncation of the range of the data. Correlation can also be a misleading average if the relationship varies depending on the value of the independent variable (this is known as "lack of homoscedasticity").

Multiple Regression Analysis

Multiple regression is used to account for (predict) the variance in an interval dependent, based on linear combinations of interval, dichotomous, or dummy independent variables. Again Garson (2004) gives further detail.

Multiple regression can establish that a set of independent variables explains a proportion of the variance in a dependent variable at a significant level (using a significance test of R^2), and can establish the relative predictive importance of the independent variables (comparing beta weights). Power terms can be added as independent variables to explore curvilinear effects and cross-product terms can be added as independent variables to explore interaction effects.

The multiple regression equation takes the form:

---

[23] Pearson's product moment correlation is often used as a measure of linear correlation for interval variables. Pearson's r varies between -1 and 1.
[24] Kendall's tau is used as a measure of linear correlation for ordinal variables.
[25] Chi-square tests examine the difference between actual frequencies and expected frequencies in a contingency table; hence the greater the difference the larger the chi-square value. The chi-square value must however be related to the significance level, either 0.05, 0.01 or 0.001 are most frequently used. The larger the contingency table, the larger the chi-square value is likely to be. Chi-square is however the weakest of the techniques employed in this section of the

$$Y = b_1x_1 + b_2x_2 + \ldots + b_nx_n + c.$$

The bs are the regression coefficients, representing the amount the dependent variable y changes when the independent changes 1 unit. The c is the constant, where the regression line intercepts the y axis, representing the amount the dependent y will be when all the independent variables are zero.

The standardised version of the b coefficients are the beta weights, and the ratio of the beta coefficients is the ratio of the relative predictive power of the independent variables. Multiple regression shares all the assumptions of correlation: linearity of relationships, the same level of relationship throughout the range of the independent variable ("homoscedasticity"), interval or near-interval data, and data whose range is not truncated. In addition, it is important that the model being tested is correctly specified. The exclusion of important causal variables or the inclusion of extraneous variables can change markedly the beta weights and hence the interpretation of the importance of the independent variables.

R^2, also sometimes called the coefficient of multiple determination, is the percent of the variance in the dependent explained uniquely or jointly by the independents. R^2 can also be interpreted as the proportionate reduction in error in estimating the dependent when knowing the independents. That is, R^2 reflects the number of errors made when using the regression model to guess the value of the dependent, in ratio to the total errors made when using only the dependent's mean as the basis for estimating all cases.

3.11 Conclusions: Commentary on the Research Method Employed

As a summary to this chapter, Table 3.7 outlines the strengths and weaknesses of the methods and statistical techniques used in this thesis. The study is cross-sectional and allows the exploration of interactions between a large number of land use and socio-economic characteristics and travel behaviour; multiple regression analysis techniques are particularly useful here in allowing an estimation of the strength of relationships to be made. Also the analysis allows an examination of temporal change, assessing the extent of co-location and travel behaviour modification over time.

There are, of course, alternative ways of carrying out this type of analysis. An alternative, additional or supplementary focus might, for example, consider all journey to work trips, measure energy consumption in a different way (for example, use a "bottom-up" assessment of individual travel behaviour, vehicle type and driving style, etc.) or use face-to-face interviews instead of questionnaires.

Table 3.7: *Strengths and Weaknesses of the Study Method*

Strengths	Weaknesses
The study evaluates the potential links between land use and socio-economic characteristics and travel behaviour and attempts to disentangle the complexity of relationships not previously well understood.	Travel behaviour is represented throughout the thesis by the commute to work: which is just 20% of total travel in the UK (Census 2001). Further research could consider all journey purposes.

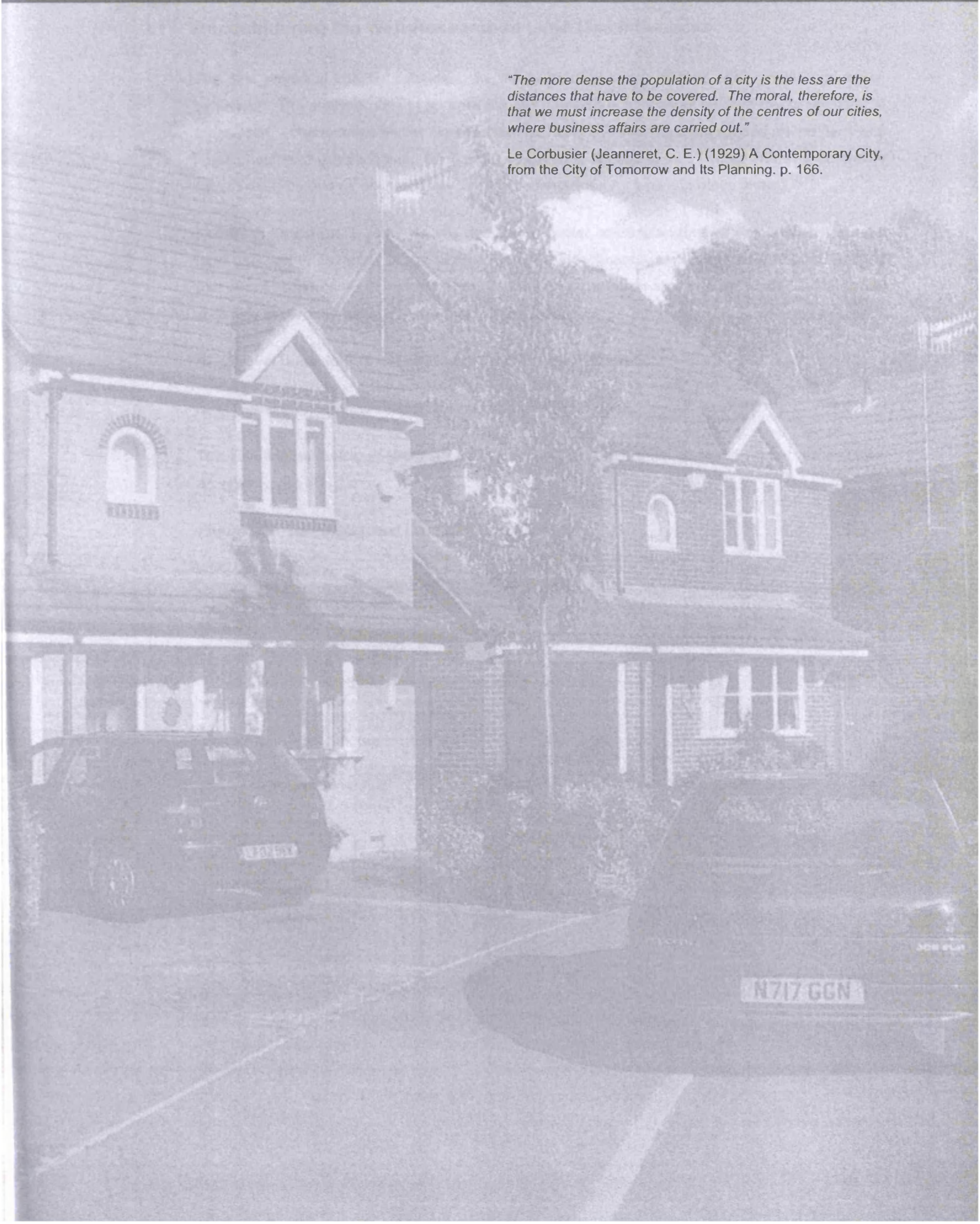
thesis; it only tells us how confident we can be that there is a relationship between variables, not the strength of the relationship.

	The focus on the commute, and the occupancy assumption this entails, means that car travel becomes highly energy consuming – more than in the case of all travel.
The study includes analysis of a number of land use and socio-economic characteristics that have not previously been well researched.	Self-completed questionnaires can be questioned in terms of reliability of data, however there was little other option available due to resource (time and cost) constraints.
The study systematically examines the temporal changes in the land use, socio-economic and travel behaviour relationship by using two rounds of survey analysis in 1998 and 2001. Detailed assessment in Chapter 6 examines the differences in travel behaviour between respondents who continue to live in Surrey and inmovers and outmovers. The matched pair analysis overcomes any potential attrition problems.	Survey sample sizes are sometimes small, especially in the matched pair analysis which is used to consider temporal changes and, within this, when disaggregations have been employed. Sample sizes have however been made evident throughout the study, with low thresholds particularly emphasised and no research conclusions been made using these.
The study looks at detailed travel behaviour patterns at the individual level and thus can pick up variability not evident at the aggregate UK-wide or regional level. Data is presented at different levels of analysis, for example, as aggregate Surrey-wide data, and disaggregated sub-groups such as density or income cohorts.	The use of UK average fuel consumption figures, and using 1993/94 based data, can be questioned. However these reflected the most up-to-date-information available when the empirical phase of the research started. A cross-check of updated figures shows no major changes in consumption figures. Further research could develop and employ updated figures.
The measurement of commute distance uses journeys through the network (using the Surrey County Council Transportation Model): this is an improvement on many studies which use crow-fly distance travelled.	Regression analysis does not identify synergies between different land use and socio-economic factors. Co-linearity analysis is however employed as well as qualitative discussion, which allows for partial assessment.
	The working method does not positively identify causality between land use, socio-economic variable and travel behaviour. Again, qualitative discussion allows for partial assessment.
	Linear regression analysis simplifies complex relationships down to a purely linear understanding. New methods (perhaps involving simulation modelling) would be useful further areas of work to help move beyond the constraints of linearity. The social field is by definition not linear.
	Temporal analysis is assessed using only a three-year time period. Modification of travel behaviour is likely to occur over a longer timeframe; however assessment of this was difficult within the thesis timetable. Further research could concentrate on longer timeframe changes.

04. Land Use Influences on Travel

"The more dense the population of a city is the less are the distances that have to be covered. The moral, therefore, is that we must increase the density of the centres of our cities, where business affairs are carried out."

Le Corbusier (Jeanneret, C. E.) (1929) A Contemporary City, from the City of Tomorrow and Its Planning. p. 166.



4. Land Use Influences on Travel Behaviour

4.1 Reconsidering the Well-Researched Land Use Influences

This first empirical chapter considers the influence of a series of land use variables on travel behaviour. The analysis aims to address the two research questions as outlined below and later in the chapter – one focused on the "well-researched" land use variables, the second on the "less well researched" land use variables. Each are considered in relation to their impact on travel behaviour (represented by energy consumption, journey distance journey time and mode share).

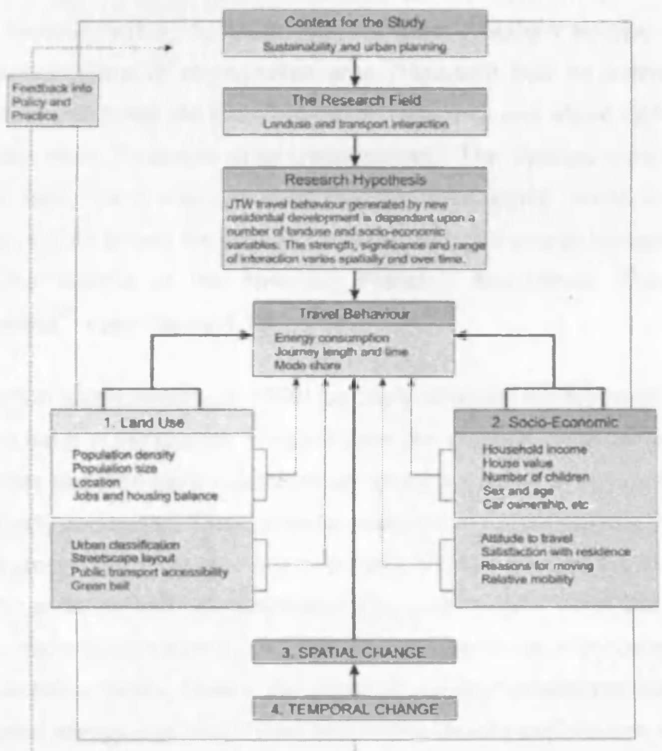
Research Question 1: How do we develop a better understanding of the well-researched land use variables: what is the scale, strength, significance and range of influence of land use characteristics – such as population density, population size and proximity to the urban area and motorway network – on travel behaviour.

H_0 – Travel behaviour is not related to land use characteristics.

H_1 – Travel behaviour is related to land use characteristics.

The key diagram below shows the relation of this part of the research to the rest of the empirical analysis.

Figure 4.1: *Well-Researched Land Use Influences*



4.1.1 Density of Development

"*New York is too big this way*", the Major of Chicago says, raising a hand above his head. Stretching both arms out at his sides, he adds, "*Los Angeles is too big this way. All the other cities are too small. We're just right.*" (From Bailey and Coleman, 1996, Wall Street Journal, August 21, pp.A1).

Such thoughts, whether we agree with them or not, encapsulate the debate surrounding the relationship of density with travel behaviour. What roles do structural features such as urban density play in people's quality of life and what contribution do they make to sustainability?

A large amount of research has concentrated on the potential impact of density on travel behaviour. Density of development is most often measured in terms of population density and, to a lesser extent, employment density. Much of the work looking at density was stimulated by the work of Newman and Kenworthy (1989a) and later by the publication of the European Commission's Green Paper on the Urban Environment, which essentially advocated compact cities with higher population densities (Commission of the European Communities, 1990). Newman and Kenworthy's analysis of fuel consumption in different international cities gave a direct comparison of carbon dioxide emissions around the world. Whilst land use intensity was only one of the factors to which automobile dependency was attributed, the basic hypothesis - that there was a relationship between density and the distance that people need to travel - was quite fundamental. The research argued that European cities were denser than either Australian or American ones, with activities concentrated in their centres, and that this was associated with a higher usage of public transport and lower energy consumption per capita. The database covered a range of indicators for 32 cities, in North America, Australia, the Far East, Western Europe and the (then) USSR. The most gasoline-intensive metropolitan area (Houston) had an estimated average usage per capita of almost 200 times the most restricted (Moscow), and about eight times as high as the most "frugal" of the West European cities (Amsterdam). The findings were based on a comparison of cities at one time, but it was assumed that this relationship would also hold for a given city over time. Figure 4.2A shows the original urban density and energy consumption correlation published in 1989 in the Journal of the American Planning Association. The analysis has subsequently been updated[26] - see Figure 4.2B.

Gordon and Richardson (1989) famously criticised the Newman and Kenworthy (NK) thesis in the next issue of the journal. They perceive the situation to be very different in California, where both homes and jobs have suburbanised, in such a way that commuting distances and times have actually decreased. They produce evidence which shows that there is no clear relationship between the proportion of car trips and population density and believe that the marketplace, quite independently from planning intervention, will "adjust" cities like Los Angeles so that car use will decrease "automatically". In 1997, and at other times, Gordon and Richardson have returned to the discussion, putting forward the classical transport economist viewpoint, for example citing the "global energy glut" and strong residential density preferences as reasons for resisting the advocacy of compact cities.

[26] See Newman and Kenworthy (1999) *Sustainability and Cities: Overcoming Automobile Dependence*, where data from 16 new cities, in Canada, Asia and the USA, has been added to the original dataset from 1989.

Figure 4.2A: *Density and Enery Consumption (Newman and Kenworthy, 1989)*

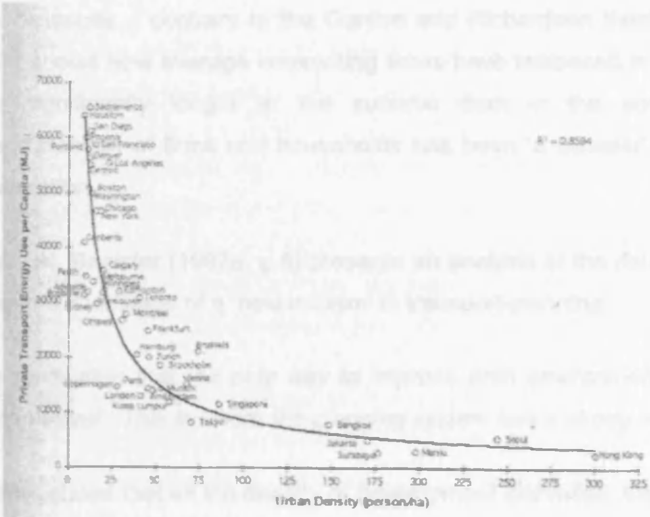
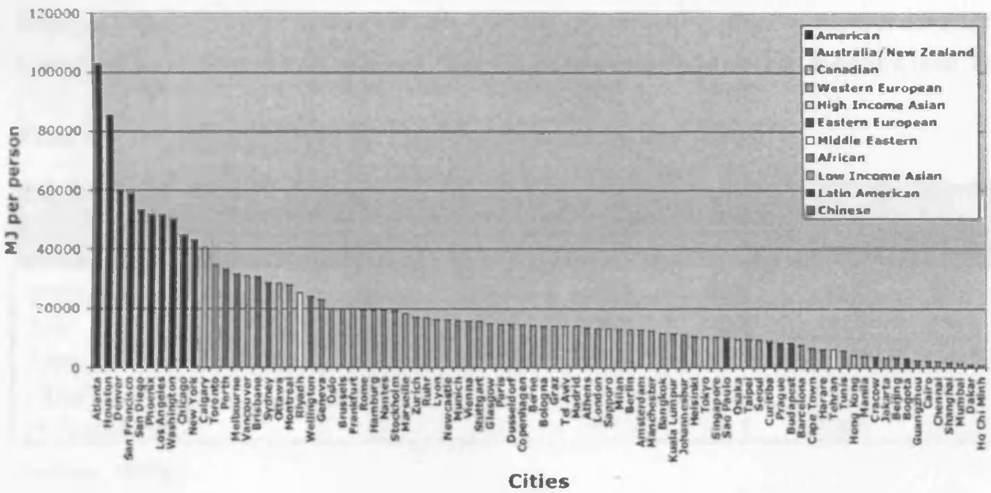


Figure 4.2B: *Density and Enery Consumption (Newman and Kenworthy, updated 1999)*



Since the late 1980s, various people have speculated as to whose model is right for reducing car use. Some identify with the Gordon and Richardson co-location thesis (see Echenique 2001; or Breheny 1990, 1992b and 1995b) whilst others sympathise with the Newman and Kenworthy viewpoint (see Bozeat et al, 1992; Headicar, 1995; and Banister, 1997a). Bozeat et al undertook research in the UK for the Departments of Transport and Environment regarding the role of planning and land use measures in reducing transport emissions. They analysed travel in relation to variables including density, urban size, centralisation and mixing, in twelve urban districts in the UK. They found that distance to work was negatively associated with population density, whilst the amount of car travel between areas was mainly accounted for by differences in population density and car ownership.

Newman and Kenworthy have also replied to the criticism of Gordon and Richardson (1989), showing how car use in the USA is continuing to grow exponentially, in both car use and journey to work distances – contrary to the Gordon and Richardson thesis of stabilisation. Similarly, Ewing (1997) shows how average commuting times have increased in metropolitan areas in the US; and were significantly longer in the suburbs than in the central cities, concluding that the decentralisation of firms and households has been 'a disaster' for travel behaviour and resource consumption.

In the UK, Banister (1997a, p.6) presents an analysis of the data at the UK-wide level. He reports on, as the final stage of a 'new realism' in transport planning:

"The realisation that the only way to improve both environment and congestion is to reduce the need to travel. This is where the planning system has a strong role to play."

Banister states that as the density of development increases, the average trip length, the use of the car, and distance travelled all reduce. Journey lengths by car are all relatively constant (at around 12km) at densities over 15 persons per hectare, but at lower densities car journey lengths increase by up to 35%. Similarly, as density increases, the number of trips by car decreases from 72% of all journeys to 51%. Car use in the high density locations is half that in the lowest density locations. From 1985/86 to 1994/96 the total distance travelled in all areas increased by 23%, but car distance increased by 32%, and with the greatest growth taking place in the low density locations. Even if car ownership is held constant, then the effects of density are still apparent (see Table 4.1).

Table 4.1: *UK Travel Distance by Car Ownership and Density 1989/91*

Distance km/person/week	0-1 persons /ha	1-10 persons /ha	10-20 persons /ha	20-35 persons /ha	>35 persons /ha	Total
0 cars	82.0	89.4	73.2	83.3	93.0	86.2
1 car	218.5	211.3	191.2	185.8	172.9	198.6
2 cars	322.7	299.5	267.7	268.0	253.2	288.4
>2 cars	324.9	332.4	267.5	305.1	264.8	311.0
All Households	220.7	218.0	181.9	180.6	158.8	197.3

(Banister, 1997a)

There is a clear trend in the data across all car ownership categories - car ownership is often used as a proxy for income - to indicate that car ownership clearly affects the amount of travel. However density also affects the amount of travel - if the difference between the high and low density figures are taken, then about 20% of the variation in travel is taken by the density variable.

Other authors have also supported the density argument. Owens (1998) shows that density is inversely related to travel demand and energy consumption, but that its significance as an independent variable is disputed. She believes that higher densities may provide "a necessary but not sufficient condition for less travel", and need not conflict with amenity.

In an influential report for the UK government, ECOTEC (1993) put forward four reasons why population density may be linked to travel patterns, as outlined below:

- Higher population densities widen the range of opportunities for the development of local personal contacts and activities that can be maintained without resort to motorised travel.

- Higher population densities widen the range of services that can be supported in the local area, reducing the need to travel long distances.

- Higher density patterns of development tend to reduce average distances between homes, services, employment and other opportunities, which reduces travel distance.

- Higher densities may be more amenable to public transport operation and use, and less amenable to car ownership and use, which have implications for modal choice.

ECOTEC contend that average travel distance by car, bus and rail decreases with increasing population density, whilst the average journey distance by foot is more or less constant, regardless of population density. However, they report that total journey frequency does not show a clear gradation with population density, and there is little variation in trip frequency according to population density. The average journey frequency is just under 14 journeys per person per week. In areas of low population density (between one and five persons per hectare), trip frequency is 14.8 journeys per person per week - six percent higher than average. In areas where population density is more than 50 persons per hectare, trip frequency is 13 journeys per person per week - seven percent lower than average.

ECOTEC also show how modal choice is associated with population density. The proportion of trips by car decreases with increasing population density, whilst the proportion of trips by public transport and foot both increase. Car trips account for 71% of journeys in low density areas, but only 51% of trips in high density areas (more than 50 persons per hectare). There is a fourfold difference in public transport trips and almost twofold difference in walk trips when comparing low and high density areas.

Hillman and Whalley (1983) report similar findings from their analysis of data from the 1978/79 National Travel Survey. They show that the total distance by all modes decreases with increasing population density, and show that residents in very low density areas (less than five persons per hectare) travel by car more than twice the distance of residents in high density areas (more than 60 persons per hectare).

And further, Frank and Pivo (1995) show how the proportion of shopping trips by public transport and the proportion of commuting trips by foot are both positively linked with population density. Kitamura et al (1997) show how population density is linked to the proportion of public transport trips, after accounting for socio-economic differences, and Ewing et al (1996) report that there is a weak but significant statistical link between trip frequency and population density.

Finally, we return - full circle - back to the sceptics: (Ian) Gordon and Breheny (1997) reflect the arguments of (Peter) Gordon and Richardson. They argue that the evidence for a relationship between density and travel behaviour is based on two key assumptions: (1) a more or less self-evident and intuitive reduction in the need to travel, and to rely on private transport, if people live closer to their places of work, sustenance and entertainment; and (2) graphic evidence from the

Newman and Kenworthy comparative studies. They however believe these are an inadequate basis for reliance on compaction as an energy-saving strategy, with problems including:

- Individuals' demand for travel, reflecting increasingly sophisticated tastes and circumstances.
- The likelihood that much of the simple association observed between densities and travel behaviour actually involves economic factors omitted from the analysis.
- The leap from the observation that average population densities in urban areas and regions may significantly affect the amount of private travel, to an expectation that achievable changes in land use will have a similar affect in changing travel behaviour.
- Implementation of planning policies in a market society is always uncertain and is likely to be particularly problematic when this plays against the balance of market forces – the unintended effects are likely to be greater than the intended.
- The ability of the planning system to manipulate densities in practice is not certain – in other words the 'implementation gap' may prove difficult – and that departures from 'perfect implementation' are not mere anomolies, but somewhat predictable outcomes.

Re-examining the Newman and Kenworthy data, Breheny et al show that the apparent influence of density is greatly reduced when two or three 'odd' cities are excluded (Hong Kong, Singapore and Moscow) and allowance is made for the effect of petrol price differences. Significantly, a doubling of densities would be required to reduce energy usage by 15%, and petrol price variations account for more of the variation in energy consumption than does density (a doubling of fuel prices could lead to a 40% reduction in energy use). Gordon and Breheny believe that, although there is ample evidence that higher densities tend to be associated with less travel, and particularly the private motor car, the effects are not all that strong. There is little evidence that more or less compact forms of development within an urban area or functional urban region (FUR) are energy saving. Gordon and Breheny take it as given that the level of energy use and emissions associated with urban transport need to be substantially reduced, however do not believe that planning policies are the most effective way of delivering this reduction. They add that the uncertainty surrounding the link between land use and energy use contrasts notably with the evidence of direct effects from variations in fuel prices, and that this would be a more reliable basis (together with the support of public transport) for an energy and emissions saving strategy. Also, higher fuel prices would tend to generate more compact settlement patterns because of the financial disincentive to travel.

So, **in summary**, what do we have? Lots of research, mainly from the US, Australia, UK and rest of Europe, all considering the density and travel relationship, but with a confused picture in terms of results and interpretation of results.

The key issue for this thesis, in terms of density and travel behaviour, is to further understand why there is such a *contradiction* in the research findings. And then move onto consider how we may gain a clearer understanding of the relationships at work. Within this, there are a number of more detailed issues:

- In what way is density associated with energy consumption and travel in Surrey?

- What difference does the *definition of density* make to the associated travel behaviour? For example, Gordon et al (1989a) define population density in terms of workplace location, whereas most other studies use location of residence. What about employment density? There is much less evidence concerning the relationship between travel patterns and employment density – which is a possible second measure of the intensity of land use and activities. For example, Frank and Pivo (1995) show that employment density, like population density, is connected to the proportion of public transport trips for both shopping and work journeys, even when socio-economic variations are controlled.

- What measure of *travel behaviour* is most useful? Newman and Kenworthy (1989a) concentrate on the correlation between population density and transport energy consumption. Journey length, journey time and mode share have also been used, but few research studies consider the range of possible variants.

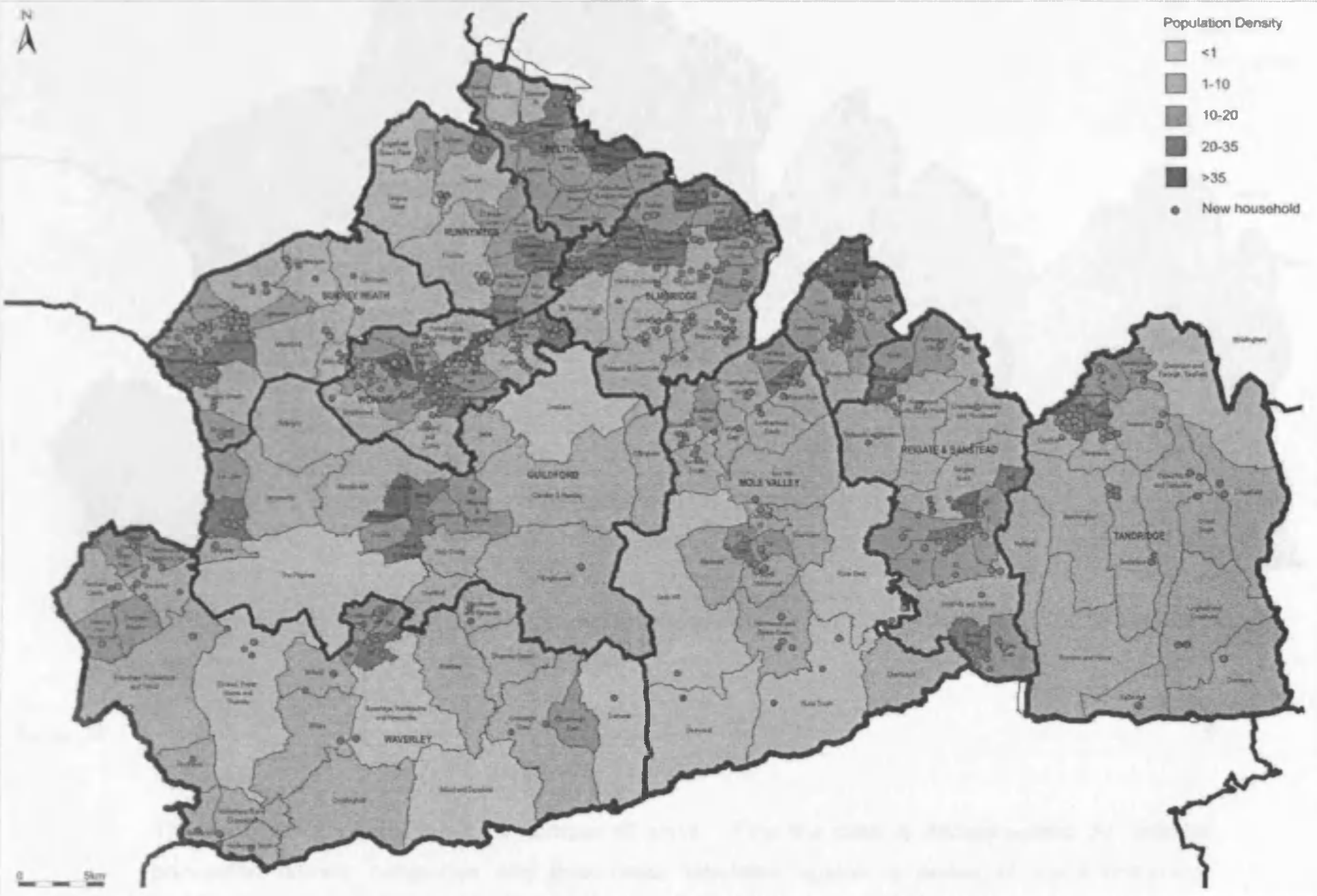
- What is the relative influence of *socio-economic* factors? Banister (1997a) holds car ownership constant and still finds a relationship between travel and density. Breheny et al (1997) counter that price is more likely to be a significant influence on an energy and emission savings strategy than land use change.

We test these issues next, using the research dataset in Surrey. Note that data is given from the New Household Occupiers Survey for 1998 and 2001. Any temporal comparisons – analysing changes over time – are however left until Chapter 6 due to potential survey attrition issues (see detailed discussion in Chapter 6 – Page 270 onwards).

EVIDENCE FROM SURREY: DENSITY AND TRAVEL BEHAVIOUR

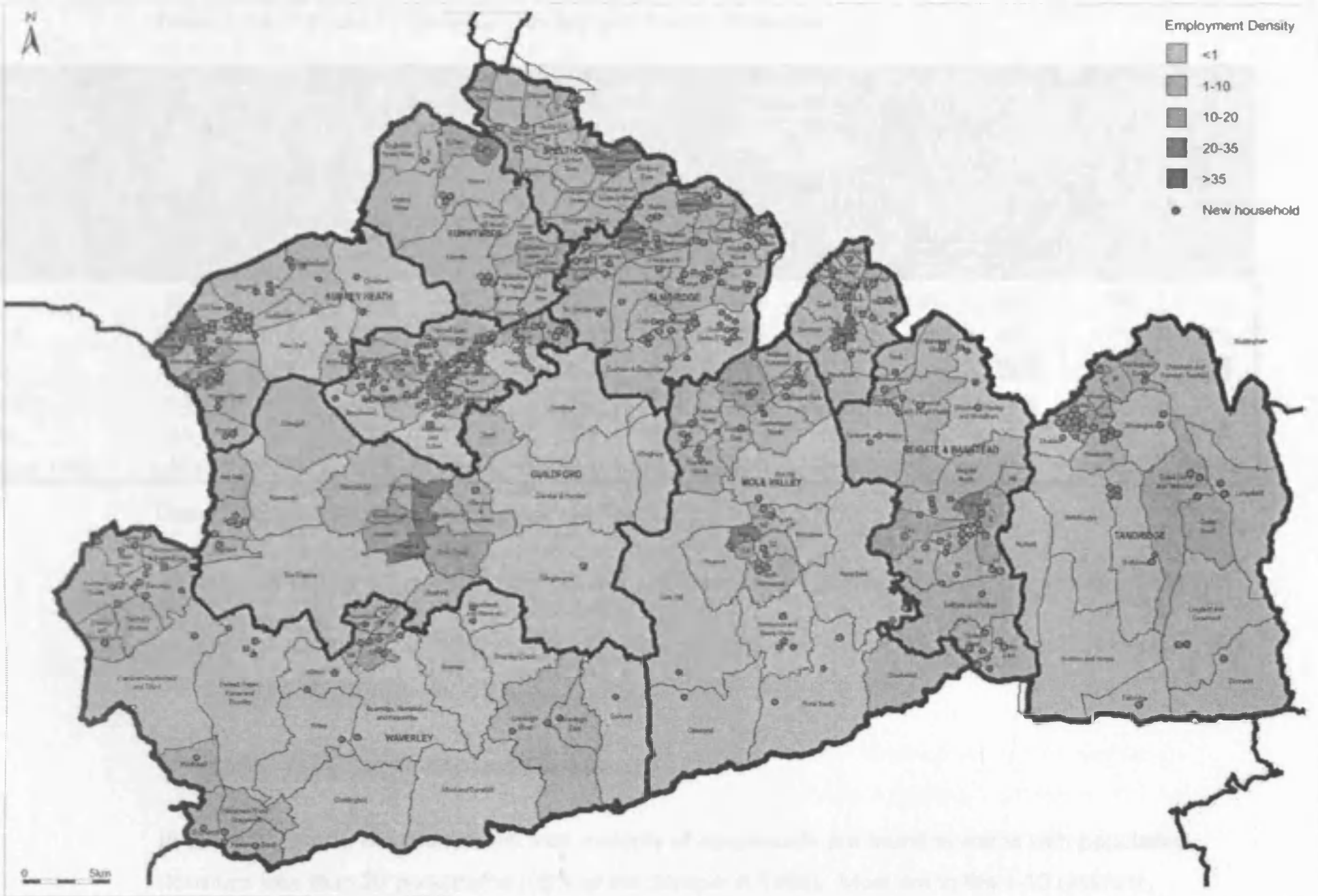
Figures 4.3 and 4.4 show the population and employment density distribution in Surrey[27].

Figure 4.3: *Population Density in Surrey*



[27] NB. Population density is defined in terms of usually resident population/hectare and employment density by workplace based jobs/hectare.

Figure 4.4: *Employment Density in Surrey*



The analysis is carried out in a number of ways. First the data is disaggregated by resident population density categories and then cross tabulated against a series of travel behaviour measures: average energy consumption, journey to work distance, time and mode share (in terms of % car driver and % train). A number of the important findings are represented graphically over the following pages. Second, as a side issue, different measures of density are used and again cross-tabulated against travel behaviour. Finally, the interaction of density and certain socio-economic characteristics is assessed.

Density and Travel Behaviour

Table 4.2A: *Resident Population Density and Travel Behaviour*

Resident Population Density	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver		% Train	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
0-1	51	20	[redacted]	[redacted]	[redacted]	[redacted]	41.2	**46.3**	75%	68%	15%	16%
1-10	609	218	62.7	[redacted]	31.1	29.3	43.3	41.6	73%	68%	17%	13%
10-20	468	136	[redacted]	58.6	30.7	29.9	41.9	43.3	72%	**62%**	16%	[redacted]
20-35	382	114	57.2	56.9	**28.5**	**27.3**	**39.4**	**37.2**	73%	72%	13%	13%
>35	143	37	**42.5**	**37.6**	**27.2**	**26.2**	43.5	42.9	**65%**	69%	[redacted]	[redacted]
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%	17%	16%

Data: Surrey New Occupiers Survey 1998 and 2001.

To help the reader more easily pick up the key trends the following notation is used in all of the tabular output:

- [redacted]: 5% > sample average
- light grey shading: 5% < sample average

In terms of sample distribution, the vast majority of households are found in wards with population densities less than 20 persons/ha (68% of the sample in 1988). Most are in the 1-10 resident persons/ha cohort (40% of the sample in 1998). These are relatively low densities: PPG3 suggests a threshold of no less than 30 dwellings per hectare net. New housing developments in England have been built recently at an average of 25 dwellings per hectare, with more than half of all new housing built at less than 20 dwellings per hectare. Such low densities make it difficult to support public transport and local services and result in a high land take.

There are a number of interesting trends in the Surrey data:

- There is a clear inverse linear relationship with population density and energy consumption: lower densities are associated with higher energy consumption and higher densities with lower energy consumption. In 1998 households at densities of over 35 persons/hectare consume 29% less energy in their journey to work than the sample average.

- Much of this inverse linear relationship is due to changes in journey to work distance and a lower car mode share; journey time remains fairly static. These results are similar to those found at the UK level (see the Banister analysis of NTS data, 1997a) and correspond with other findings (for example, Newman and Kenworthy, 1989a).

- Car mode share is highest in low density areas and lowest in high density areas, markedly so. Train mode share is highest in the high density areas.

Correlation analysis shows that increased residential population density is significantly associated with reduced energy consumption (in both the 1998 and 2001 datasets), and journey distance (in the 1998 dataset). Remember here that the strong correlation between density and travel is made up of a number of parts – travel (in composite energy consumption terms) is a combination of journey distance, mode share and occupancy.

Table 4.2B: *Resident Population Density and Travel Behaviour*

Land Use Variable	Correlation	EC98	EC01	JD98	JD01
respopde	Pearson Correlation	-0.132**	-0.132**	-0.058*	-0.071
	Sig. (2-tailed)	0.000	0.002	0.019	0.105

***Correlation is significant at the 0.01 level (2-tailed)*

**Correlation is significant at the 0.05 level (2-tailed)*

Analysis of the Surrey data therefore strongly supports much of the evidence available in the literature: that new households located in higher density areas are associated with reduced energy consumption (for example, Newman and Kenworthy, 1989 and 1999; and Banister, 1997a). The following figures summarise the data in terms of boxplot distribution and bar chart density cohort.

Multi-criteria analysis is used in Chapter 7 to assess the complex, combined relationships between density (and other land use and socio-economic factors) and energy consumption patterns.

There remains however a difficulty in the density debate: previous research on density has used different definitions of density and, unsurprisingly, arrived at different findings. Gordon and Richardson, for example, use workplace population density. This issue is considered below.

Figure 4.5: *Resident Population Density and Energy Consumption 1998*[28]

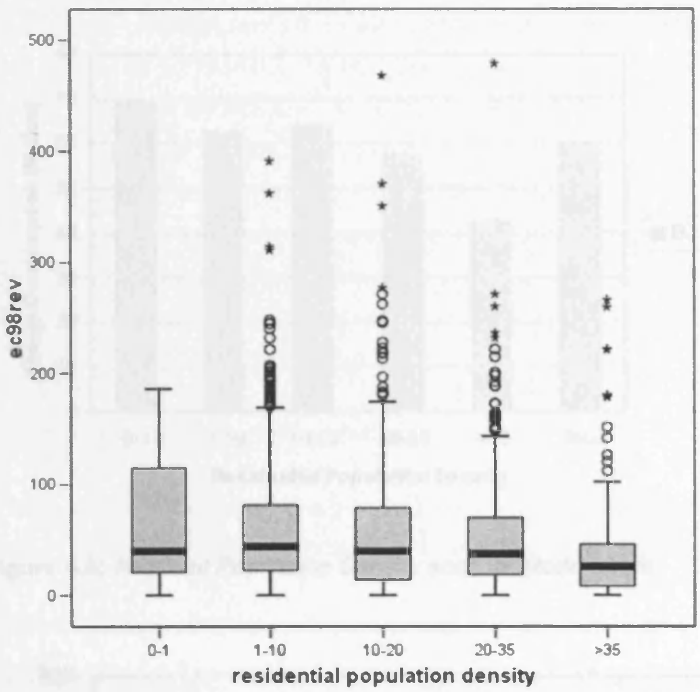
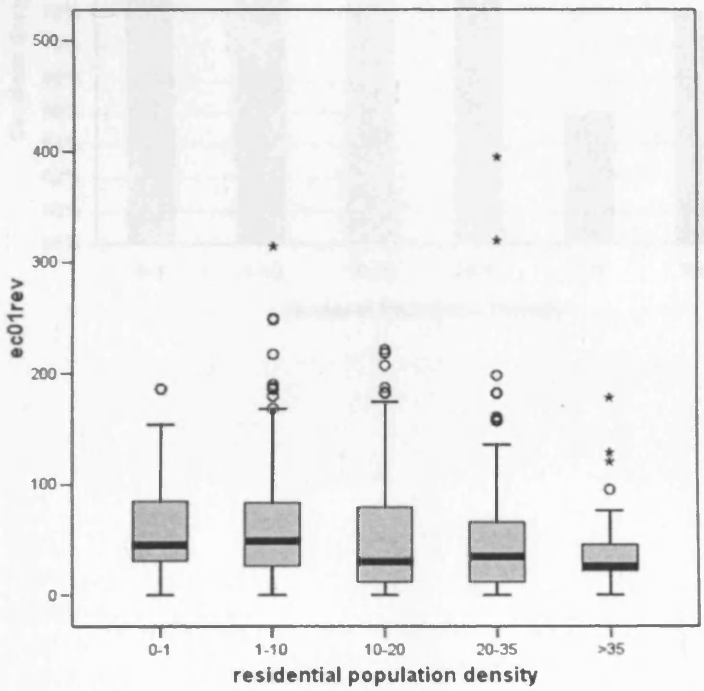


Figure 4.6: *Resident Population Density and Energy Consumption 2001*



[28] Note that in the boxplot outputs the median average is shown by the central black line; whereas in the previous tabular outputs the mean average is shown.

Figure 4.7: *Resident Population Density and Energy Consumption*

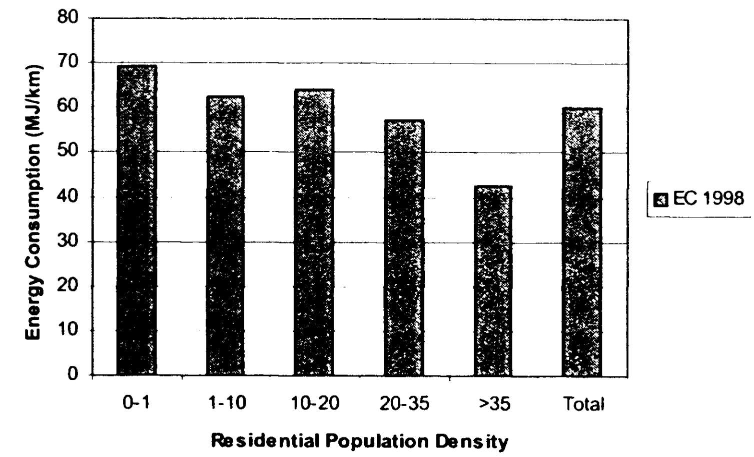
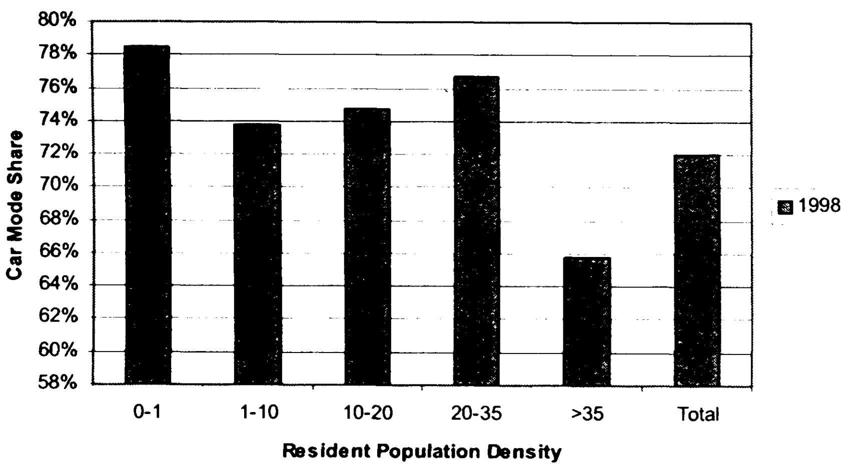


Figure 4.8: *Resident Population Density and Car Mode Share*



Different Definitions of Density: What Difference Do They Make?

Most research studies are set up with varying assumptions. This can be critical when comparing what appear to be differing results. For example, many previous research studies covering the density and travel debate have used varying definitions of density. Most use resident population density, but there are at least three other options: resident employment density, workplace population density and workplace employment density. Newman and Kenworthy (1989a and 1999), for example, use resident population density; Gordon and Richardson (1989a) use workplace population density and Frank and Pivo (1995) have looked at workplace employment density. Below the different variants are explored in Surrey in terms of their relationship with energy consumption, and using 1998 data.

Density and Energy Consumption

Tables 4.3 and 4.4 show in more detail what happens with the density and energy consumption relationship when different definitions of density are used.

Table 4.3: *Resident Density Definitions and Energy Consumption*

Density	Average of Energy Consumption (MJ/jtw)			
	Resident Population Density		Resident Employment Density	
	Count	EC 98	Count	EC 98
0-1	51	[illegible]	268	[illegible]
1-10	609	62.7	956	62.2
10-20	468	[illegible]	338	46.2
20-35	382	57.2	88	[illegible]
>35	143	42.5	3	21.6
Grand Total	1,653	60.1	1,653	60.1

Shading Key
█: 5% > sample average
Y: 5% < sample average

Data: Surrey New Occupiers Survey 1998. (NB. Sample size notation: *<20, **<10 respondents)

Table 4.4: *Workplace Density Definitions and Energy Consumption*

Density	Average of Energy Consumption (MJ/jtw)			
	Workplace Population Density		Workplace Employment Density	
	Count	EC 98	Count	EC 98
1-10	344	[illegible]	597	[illegible]
10-20	305	36.4	180	48.8
20-35	138	45.2	12	[illegible]
Gatwick	25	[illegible]	25	[illegible]
Heathrow	76	[illegible]	76	[illegible]
Inner London	324	50.6	324	50.6
Outer London	308	[illegible]	308	[illegible]
Rural	107	39.8	107	39.8
Total	1,653	60.1	1,653	60.1

Shading Key
█: 5% > sample average
Y: 5% < sample average

Data: Surrey New Occupiers Survey 1998. (NB. Sample size notation: *<20, **<10 respondents)

The land use and energy consumption relationship varies greatly according to the definition of density used. The expected relationship of density being inversely related to energy consumption does not always appear, i.e. higher densities are not always associated with lower energy consumption patterns. For example:

- Resident population density: as seen previously, has an inverse relationship with energy consumption. In 1998, the lowest category (0-1 resident population/hectare) is associated with an average energy consumption 15% higher than the sample average and 63% higher than the highest density category (>35 resident population/hectare).

- Resident employment density: an inverse relationship appears to hold with energy consumption and journey distance. In 1998, the lowest categories (0-10 workplace based jobs/hectare) are associated with higher average energy consumption than the sample average and the higher density categories (>35 workplace based jobs/hectare).

- Workplace population density: apparently no clear relationship evident between density and energy consumption. However, the highest energy consuming categories are associated with journeys to the lowest density workplace locations, such as those found in Outer London, and also Heathrow and Gatwick. This is therefore a reflection of car dependent journeys (there is often little public transport option).

- Workplace employment density: apparently no clear relationship between density and energy consumption evident, however journeys to Outer London and Heathrow are particularly heavy in energy consumption.

In terms of strength of relationships, correlation and chi-square analysis (matched to the type of data available) shows significant relationships for all of the density definitions - between residential population density, residential employment density, workplace population density and workplace employment density and travel behaviour.

Table 4.4B: *Population Density Definitions and Travel Behaviour*

Land Use Variable	Correlation	EC98	JD98
Residential population density	Pearson Correlation	-0.132**	-0.058*
	Sig. (2-tailed)	0.000	0.019
Residential employment density	Pearson Correlation	-0.127**	-0.075**
	Sig. (2-tailed)	0.000	0.002

Chi-Square Test	Value	df	Asymp. Sig. (2-sided)
Workplace population density-EC98			
Pearson Chi-Square	230.022 [a]	12	0.000**
Likelihood Ratio	231.789	12	0.000
Linear-by-Linear Association	3.001	1	0.083
[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 6.26.			
Workplace employment density-EC98			
Pearson Chi-Square	127.821 [b]	12	0.000**
Likelihood Ratio	123.288	12	0.000
Linear-by-Linear Association	0.123	1	0.726
[b] 0 cells (0%) have expected count less than 5. The minimum expected count is 6.26.			

N = 1,653 in 1998

***Correlation is significant at the 0.01 level (2-tailed)*

**Correlation is significant at the 0.05 level (2-tailed)*

Density, Potential Socio-Economic Influences and Travel Behaviour

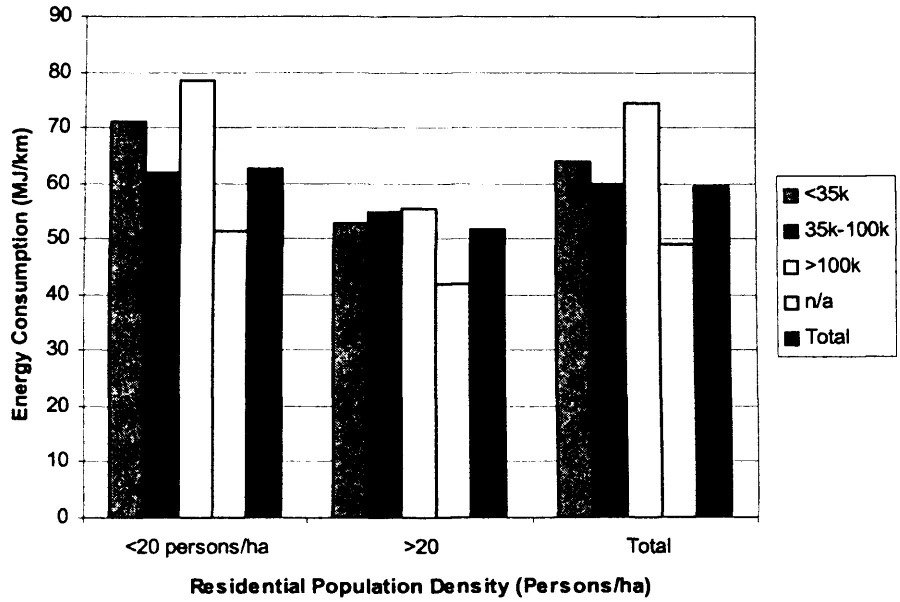
The world, obviously, does not consist of a series of bi-variate relationships. In an affluent county like Surrey, socio-economic characteristics are likely to play an important role in influencing travel behaviour. Owens (1998) even suggests that in the most affluent areas, land use form is likely to play less of a part in travel behaviour. Some of the previous literature examines this issue by holding certain variables constant and Table 4.5 builds on this by taking an initial look at the effect of household income on density and energy consumption. More detailed analysis of income and other socio-economic factors takes place later in the thesis using multi-variate analysis (see Chapter 5, page 164 onwards).

Table 4.5: *Density, Household Income and Average Energy Consumption (MJ/jtw)*

Residential Population Density	Household Income 2001									
	<35k		35k-100k		>100k		n/a		Total	
	Count	EC01	Count	EC01	Count	EC01	Count	EC01	Count	EC01
< 20 persons/ha	50	[redacted]	184	61.9	45	78.6	95	51.4	374	62.6
> 20 persons/ha	29	52.8	78	54.8	10	55.6	34	42.0	151	51.8
Grand Total	79	64.0	262	59.8	55	74.4	129	48.9	525	59.4

Data: Surrey New Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents); NB. Income data was not available from the 1998 survey. N/a - not all respondents answered the household income question.

Figure 4.9: *Density, Household Income and Average Energy Consumption (MJ/jtw)*



Energy consumption is clearly higher with the highest household incomes; household incomes over £100k consume on average over 25% MJ/trip more than the sample average. The lowest household income band of less than £35k however consumes 8% MJ/trip less than the sample average – suggesting that lower income groups are spending a disproportionate amount of their income on travel - potentially there may be housing affordability issues here, where lower income groups are having to commute longer distances to work.

We might expect lower density areas to be more energy consuming than higher density areas across all income bands and this is shown in the Surrey data. Other factors appear to be important; amongst these will be the high number of commuters to London by train (relatively high energy consumers because of the distance, upto 60km, to London) and many of these commuters will live in the relatively higher density areas in Surrey, which are also those areas most accessible to the rail network. Consistent with the thoughts of Owens (1998), within the lowest income band (<£35k) and as density increases, energy consumption falls by a large margin, i.e. for those with less choice financially, land use plays more of a part in influencing travel behaviour.

Certain cohorts - the 'extreme' energy consumers - are consuming a highly disproportionate amount of energy in their journey to work trips, almost with USA-like travelling patterns. For example, households with incomes over £100k and located in the lowest density areas, consume 32% MJ/jtw more than the sample average.

Density: summary thoughts

So, what has been learnt in terms of density and travel behaviour? Initially we should note the innovation in terms of the methodology employed: a wide-ranging review of the effects of density allows comparisons of different definitions of density (population and employment, and resident and workplace-based). The use of different measures of travel behaviour (journey length, time and mode share, and energy consumption) allows a detailed understanding of the different variables that make up overall energy consumption patterns and the urban/rural fringe location of Surrey allows non-urban centric/suburban results to be considered. Below the key findings are summarised:

Few new residential developments have been built at sufficient densities to support public transport usage; they are are seldom related to the public transport network and many are highly car dependent. Transport and urban planning can, and should, be mutually supportive wherever possible (classic car dependent new development, Godstone, Tandridge)

- Residential population density has a clear inverse relationship with travel behaviour in Surrey. Lower densities are associated with higher energy consumption and higher densities with lower energy consumption (in accord with the general findings of Newman and Kenworthy, 1989a and 1999). For example, in 1998, respondents living in areas with densities of over 35 resident persons/ha consume 29% less in average journey to work energy consumption than the sample average.
- The land use and travel behaviour relationship varies greatly according to the definition of density and travel behaviour used. Density is at times, but not always, inversely related to travel behaviour in Surrey and the strength and type of relationship varies according to definition of density (in accordance with the Newman and Kenworthy 1989a thesis, but also the Gordon and Richardson 1989 thesis).

- The influence of socio-economic factors on the land use and travel behaviour relationship is interesting. Across all income categories, energy consumption rises with increased residential population density.

Within the range of choice for Surrey, the optimum locations for future housing location, in terms of using density to help reduce energy consumption, appear to be the higher density locations – areas with at least 20 residents per hectare and 20 workplace-based jobs per hectare. Areas around key public transport nodes can be developed at much higher densities However, critically, this is not a 'one size fits all' solution, as might be implied in guidance such as PPG13. Different urban areas – within similar density ranges – are associated with very different travel characteristics. This issue is explored in more detail later in this Chapter).

Importantly new development needs to be built at much higher densities than previously found in Surrey - whilst maintaining high quality in urban design and quality of life. The urban renaissance agenda - focused mainly on the large urban areas in the UK - needs to be translated into a workable solution for the urban fringe and suburban areas such as Surrey. 40 dwellings per hectare and much higher is appropriate around the major public transport hubs in Surrey.

Empirically, we need to begin to look in more detail, beyond merely the (usually-researched) aggregate level, to get a fuller understanding of what is going on in terms of land use and travel behaviour. It is at the local level that data availability usually begins to pose problems. However, with a database such as available in Surrey, we can start to look at the urban form and density relationship all along the spatial scale: from the individual to the urban area, district, and county-wide levels. Multi-variate analysis also needs to be carried out, to help assess the likely interplay of a number of land use characteristics on travel behaviour. This is undertaken later in the thesis (see Chapter 7, page 307). Critically, bivariate analysis - considering just the density variable against travel behaviour - is only going to tell us part of the story. The factors underlying travel are much more complex.

A number of caveats should be considered to the findings. The Breheny and Gordon (1997) concern, which was noted at the start of this section, is important. Fuel price changes are likely - as a single initiative - to be more effective to an energy saving strategy than changes to density. Interestingly fuel prices were increased up to 2000 using the 5% p.a. fuel price escalator - ending in controversy with the fuel price protests.

Breheny also suggests that there is likely to be a degree of multi-collinearity between density, income, price and other transport variables, which would tend to exaggerate the apparent effect of density on energy use in simple bivariate comparisons: this issue is examined later in the thesis (in Chapter 7). Finally, the type of journey used should also be considered. This thesis and others, for example Gordon et al (1989a), focus only on journeys to work, rather than all journey purposes, which are included in the analysis of ECOTEC (1993) and Kitamura et al (1997). These non-journey to work trips could be the subject of future research in this area.

In terms of the important policy implications arising, the critical finding is that density should play a leading role in the future (sub)urban renaissance in Surrey and indeed in the wider south east region. Polycentric compaction will not lead directly to a reduction in actual travel, but if well-designed, can be an important supporting tool in achieving sustainable travel and quality of life objectives. A pragmatic policy approach would be to combine a range of measures aimed at reducing travel, including land use and fiscal change. The difficulty is that raising densities and charging for travel are currently policy "taboos" in Surrey. The future debate will be centred on achieving progress here.

4.1.2 Settlement Size

The size of settlement is also seen by many authors as a key determinant of travel behaviour. The general thesis being that the larger the settlement size, the shorter the trips and greater the proportion of trips by public transport. Diseconomies of size can however appear for the largest conurbations, as trip lengths increase to accommodate the complex structure of these cities.

Newman and Kenworthy (1999), for example, highlight evidence from Australian settlements, showing that as cities get larger they become more efficient. Their original global cities study (1989) showed a similar pattern: transport energy use per capita generally declines as city size increases. Naess (1993a and 1996) investigated this phenomenon, but attempted to eliminate the major variable of cultural difference that clearly influences a survey of global cities. He chose 22 Scandinavian cities and found a clear relationship between the size (as well as density) of the city and its per capita transport energy use. Copenhagen, Oslo and Stockholm were significantly lower in transport energy use per capita than smaller provincial towns. Numerous urban economists have pointed to the efficiency advantages of scale, for example: Hoch, 1976; Sternlieb, 1973; and Richardson, 1973. The benefits are generally associated with economies of scale: public transport sytems become more efficient as cities grow.

Banister (1997a) gives a summary of data in the UK. In terms of sustainability, he views the debate as concentrating on the appropriate minimum threshold size for a 'transport-sustainable settlement'. There seems to have been some convergence on a minimum size of 25,000 population (around 10,000 dwellings). However, here there are some concerns: settlements of that size would still generate substantial amounts of activity imbalance. Most travel, particularly by car, is generated in settlements smaller than 25,000 population (see Table 4.6). Importantly, these settlement sizes are where much of the new housing allocations will be located in the current Local Development Frameworks being prepared in the UK. In transport terms this does not appear to be fostering sustainable trends.

Table 4.6: *Travel Distance by Settlement Size and Mode*

Settlement Size	Kilometres per Person per Year 1985/86			Kilometres per Person per Year 1992/94			% Increase over 8 Years	
	Car (% of total distance)	Other	Total	Car (% of total distance)	Other	Total	Car	Total
London	5,147 (63%)	3,003	8,149	5,481 (67%)	2,760	8,241	6.5%	1.1%
>250,000	4,933 (66%)	2,504	7,437	6,445 (73%)	2,356	8,801	30.7%	18.3%
100-250k	6,194 (72%)	2,441	8,636	8,483 (80%)	2,184	10,666	37.0%	23.5%
50-100k	5,919 (71%)	2,369	8,288	8,291 (79%)	2,210	10,501	40.1%	26.7%
25-50k	6,006 (73%)	2,173	8,178	7,657 (78%)	2,105	9,762	27.5%	19.4%
3-25k	7,144 (76%)	2,369	9,413	9,498 (80%)	2,445	11,943	33.0%	26.9%
<3,000	8,832 (78%)	2,525	11,357	11,003 (82%)	2,482	13,484	24.6%	18.7%
Overall	6,109 (71%)	2,449	8,558	7,972 (77%)	2,390	10,362	30.5%	21.1%

(Banister, 1997a)

Banister shows how settlement sizes of 25,000-50,000 have lower travel distances in both 1985/86 and 1992/94 than settlements, which are either larger or smaller, and dependence on the car is lower. Growth rates in these settlements have been lower than the national average; Banister asks whether development should be targeted at this size range.

Table 4.7 illustrates these 'size' relationships more clearly with car ownership as the isolated variable. In non-car owning households, people in London, rural areas and settlements of 50,000 to 100,000, all travel significantly further than one would expect. Similarly patterns can be found in other car ownership categories. People in rural areas travel 36% above the average distance, and above average figures are found in the 3,000-25,000 settlement size category. Below-average figures are found in the metropolitan areas and in cities with over 250,000 population. Here, travel patterns and dependence on the car has increased over time, but at a lower rate than the national average. In transport terms, it is these larger settlements that produce the more sustainable transport patterns, and provide clues as to where land use and transport policies have been best integrated. Banister (1996) argues that a diversity of services and facilities requires a population size of at least 25,000 and preferably 50,000. Barton et al (1995) share similar views on settlement size thresholds.

Table 4.7: *Variation in Travel (1989/91) by Car Ownership and Settlement Size (Distance/Person/Week)*

Settlement Size	Car Ownership				Overall
	0	1	2	>2	
London	+15%	-8%	-5%	-18%	-8%
Metropolitan	-5%	-15%	-17%	-4%	-23%
>250,000	-7%	-10%	-8%	-4%	-11%
100-250k	-8%	+3%	-12%	+1%	-3%
50-100k	+11%	+6%	-8%	-8%	-1%
25-50k	-1%	-3%	+1%	-12%	-2%
3-25k	-10%	+9%	+7%	+7%	+12%
Rural	+17%	+17%	+23%	+19%	+36%
Average (km)	86.2	198.6	288.4	311.0	197.3

(Banister, 1997a)

Hillman and Whalley (1983) report similar findings in their analysis of data from the National Travel Survey in 1978/79. They report that the total distance travelled per person by car, and average journey distance, is lowest in conurbations and highest in rural areas.

More sceptical views are however found. Economists such as Neutze (1977) point to the diseconomies associated with size due to the growth in externalities. Others stress that social problems can increase with city size and density (Troy, 1996). Fischer (1976, p.250) summarises the elusive search for optimal city size in the following way:

"Most urban scholars seem convinced, to quote a British economist, that the search for an optimal city size is almost as idle as the quest for the philosophers' stone (Richardson, 1973). The entire area of speculation is misconceived on several grounds. First there are no substantial empirical findings pointing to city size at which any 'good' – income, innovation or government efficiency – is maximised, or any 'bad' – crime or pollution – is minimised. In fact, some data suggest that for

economic purposes an optimal city size would be larger than we now have ... Even if such ideals could be found, they would probably not be the same for a wide variety of social products. The size that maximises personal incomes would differ from that which maximises artistic creativity, or that which minimises pollution, and so on. And it would surely be a vain task to try to sum up all these various 'goods' and 'bads' into a single measure."

Similarly, Owens (1986) and ECOTEC (1993) believe it is unlikely that there is a simple relationship between settlement size and travel patterns. ECOTEC, using data from the National Travel Survey 1985/96, report that travel distance is highest in the smallest category of settlements (less than 3,000 residents), and lowest in large metropolitan areas (excluding London). Residents of London travel larger distances, on average, than residents of the next six largest metropolitan areas – the West Midlands, Greater Manchester, West Yorkshire, Glasgow, Liverpool and Tyneside.

Again, some of the evidence from the United States is sceptical in nature. Gordon et al (1989a) show no identifiable correlation between urban population size and modal choice. Drawing on data from the Nationwide Personal Transportation Study (NPTS), Gordon and Wong (1985) analysed the commuting distances for private vehicles in American metropolitan areas with more than 100,000 inhabitants. They found that the average journey to work lengthens in accordance with city size in the Northeast of the USA. However, for cities in the West, the average distance decreases with increasing city size for metropolitan areas with at least three million inhabitants. Compared with the Northeast, the distance travelled in Western cities in the US is smaller in most size classes during the morning peak. The proportion of car journeys was found to be least in New York (which has the largest population of the areas studied) and highest in Detroit (the sixth largest population). Gordon and Wong explain these differences by referring to the fact that the western cities are more 'polycentric' than cities in the Northeast. Much of the research in the US has focused on the journey to work, which is surprising as all journey purposes are included in the NPTS.

Some commentators add that the search for sustainability shouldn't reflect a static state of affairs or indeed a series of statistical relationships. For example, a current location generating poor travel trends, may be made more sustainable (and travel patterns 'improved') by improving neighbourhood design, which may include increased densities and enhanced walking, cycling and public transport networks. Thinking of this type is behind much of the new urban design and master planning agenda, see for example the Urban Task Force (1999) or the Urban Design Compendium (Llewelyn-Davies, 2000). The similar thrust of the New Urbanism movement[29] in the United States is that communities need to be physically designed with infrastructure appropriate for the scale of the community. For example, vast suburbs can be given new coherence when focused around new sub-centres, ideally with good public transport access. In the US this has been termed public transit orientated development.

This strong emotional appeal for 'smallness' also has connections back to the work of environmentalists such as Schumacher (*Small is Beautiful*, 1973). His attack on modern gigantism has, as its key message, that all technology needs to be at the appropriate scale of the community

[29] See, for example, Calthorpe (2001) *The Regional City*, Katz (1994) *The New Urbanism* or Duany and Plater-Zyberk (2000) *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream.*

that it is meant to be serving. The recognition of this need for community scale is not necessarily at odds with more urbanist thinking. Community scale can be the appropriate focus for infrastructure within big cities.

What does this mean for future optimum urban form? Although some dissenters may refer to a number of discreditied attempts to radically 'socially engineer' or affect the growth of cities - such as the artificial constraining of city size in Moscow, or de-urbanisation philosophies such as those Mao in China - this (obviously) does not mean that all planning of city size leads to unpleasant outcomes. The size and form of cities can be positively managed. Although many cities are heading in the wrong direction in sustainability terms, the systematic dismantling of cities is not a realistic or satisfactory aspiration. Newman and Kenworthy (1999) believe that the diversity of cities around the world appears to be their main attraction: vitality and human opportunity is their key driving force. The urban advantage needs to be encouraged, not denied.

In terms of the potential affect on travel behaviour, some commentators on the concept of the compact city (for example Breheny, 1992b) agree that a combination of size, centralisation and density have an impact in reducing car dependence. But, adding a further caveat, to advocate compact cities is not necessarily to advocate centralisation in all cities regardless of size. The concept of 'decentralised concentration' or polycentricity finds favour amongst some researchers. Here, built development is focused in a number of accessible centres within the urban fabric (see Owens, 1986 and 1992; or Jenks et al, 1997). Many authors see this approach as not incompatible with the concept of the compact city, providing a practical approach to cities which are already too large to work efficiently with only one centre. Jenks et al (1997) provide viewpoints both for and against the compact city, but draw the conclusion that 'decentralised concentration' is the most efficient form in reducing car travel.

So, **in summary**, what do we have? Again, lots of research, again mainly from the US, UK and rest of Europe and Australia, all considering the population/settlement size and travel relationship, but with a confused picture in terms of results and interpretation of results.

The key issue for this thesis, in terms of settlement size and travel behaviour, is to further understand why there is such a *contradiction* in the research findings and then move onto consider how we may gain a clearer understanding of the relationships at work. Within this, there are a number of more detailed issues:

- What impact does resident settlement size have on the associated travel behaviour?
- What difference does the definition of settlement size make to the associated travel behaviour? Most authors, for example Banister (1997a), use resident population size as the independent variable. We consider population size in terms of resident and workplace location.
- What measure of travel behaviour is most relevant? Much of the research uses distance travelled. We consider the influence of energy consumption, journey length, journey time and mode share.
- What is the relative influence of socio-economic factors? Banister (1997a), for example, holds car ownership constant and finds a relationship between variation in travel and settlement size.

- Finally, within the range of choice in an area like Surrey, where are the most appropriate locations for future housing development in terms of settlement size and travel behaviour? Are they within the recommended 25,000-50,000 range (from Banister, 1997a) and should settlements below 3,000 (ECOTEC, 1993) be avoided?

EVIDENCE FROM SURREY: SETTLEMENT SIZE AND TRAVEL BEHAVIOUR

To examine the settlement size issues the data is disaggregated, for both resident and workplace locations, as follows:

- Key towns: Guildford, Woking, Epsom, Camberley, Ewell, Farnham and Redhill, all of which have populations over 25,000 persons.

- Other 33 towns in Surrey: Addlestone, Ash, Ashford, Ashtead, Banstead, Bookham, Byfleet, Caterham, Chertsey, Cobham, Cranleigh, Dorking, Egham, Englefield Green, Esher, Fetcham, Frimley, Godalming, Haslemere, Hersham, Horley, Leatherhead, Molesey, Oxted, Reigate, Shepperton, Staines, Stanwell, Sunbury, Walton-on-Thames, Warlingham, West Byfleet, Weybridge. All of these towns are below 25,000 persons in size.

- Other rural areas.

Figure 4.10 shows the settlement size distribution in Surrey (NB. settlement size is defined in terms of usually resident population).

Figure 4.10: *Settlement Size in Surrey*

Resident Settlement Size

Table 4.8A: *Resident Settlement Size and Travel Behaviour*

Town/Area	Settlement Size		Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver		% Train	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
7 Key Towns (sub total)	-	-	339	100	66.9	58.9	30.8	[illegible]	41.8	[illegible]	73%	65%	15%	[illegible]
[illegible]	64,681	65,782	[illegible]	[illegible]	58.2	92.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	56,422	56,059	33	31	65.3	69.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	36,647	[illegible]	[illegible]	[illegible]	45.0	30.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	36,289	35,924	[illegible]	[illegible]	[illegible]	68.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Camberley	34,949	[illegible]	[illegible]	22	38.2	67.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Redhill	31,892	32,654	20	[illegible]	37.7	40.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Epsom	29,090	[illegible]	[illegible]	13	35.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other 33 Towns (all below 25,000 population threshold size)	-	-	751	225	55.5	54.0	29.1	26.6	41.3	38.5	69%	66%	18%	16%
Other Rural (wards not within 40 Surrey towns)	-	-	562	200	62.5	65.6	31.1	[illegible]	43.0	42.3	76%	71%	16%	13%
Grand Total (Surrey population)	1,037,000	1,047,750	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%	17%	16%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

▌: 5% > sample average

Y: 5% < sample average

As we can see travel behaviour varies hugely between the different urban areas. In drawing conclusions we need to be very careful about sample size.

- Respondents are spread between the different towns, however mostly concentrated in the 'other 33 towns' or 'other rural' categories (45% and 33% of the sample in 1998; 42% and 38% in 2001 respectively). New household growth in 1998 and 2001 was by no means focused in the largest towns in Surrey, and not within the suggested 25,000-50,000 range (Banister, 1997).

- There is not a clear inverse linear relationship with settlement size and travel behaviour. But there are a number of interesting patterns:

  - Redhill, Epsom and Ewell are associated with the smallest average energy consumption patterns, mainly due to short journey to work lengths, suggesting some level of self-containment, and low car mode shares.

  - Within the 25,000-50,000 suggested population range (Banister, 1997) there is considerable difference in travel behaviour. For example, Camberley and Farnham are associated with high energy consumption patterns; mainly due to their high average journey to work distances and high car mode shares. This may be a function of remote locations and/or locations near to relatively uncongested road networks - the M3, A31 and Blackwater Valley Route – which facilitate lengthy commuting patterns. We explore this issue of location adjacent to transport networks later in the thesis (see Chapter 4, page 98).

  - Towns below the 25,000 population threshold and particularly the rural locations are associated with relatively high energy consumption patterns, higher than the sample average at least.

Correlation analysis reveals that the relationship between settlement size and energy consumption and journey distance is weak; certainly weaker than the relationship between density and travel – there is no significant relationship at the 1% or 5% level.

Table 4.8A: *Resident Settlement Size and Travel Behaviour*

Land Use Variable	Correlation	EC98	EC01	JD98	JD01
respopsize	Kendall's Tau	-0.024	0.007	0.001	-0.035
	Sig. (2-tailed)	0.300	0.864	0.972	0.428

***Correlation is significant at the 0.01 level (2-tailed)*

**Correlation is significant at the 0.05 level (2-tailed)*

The following figures summarise the Surrey data in terms of distribution and settlement size cohort.

Figure 4.11: *Resident Settlement Size and Energy Consumption 1998*

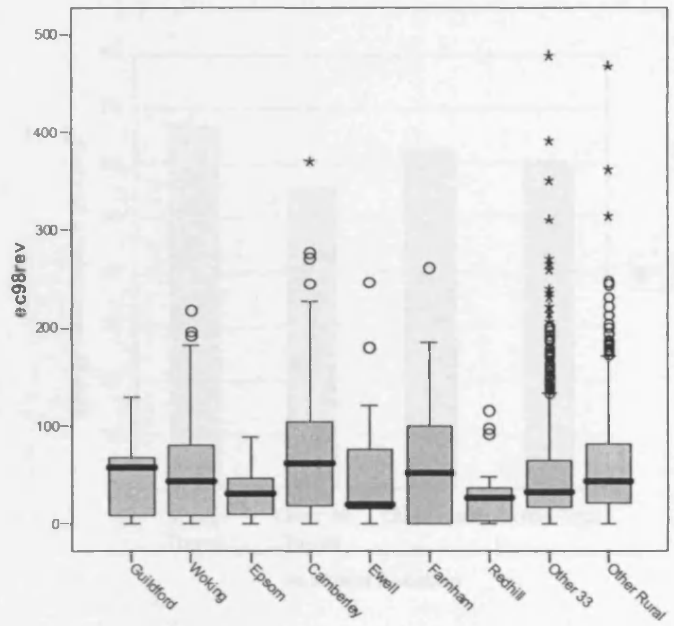


Figure 4.12: *Resident Settlement Size and Energy Consumption 2001*

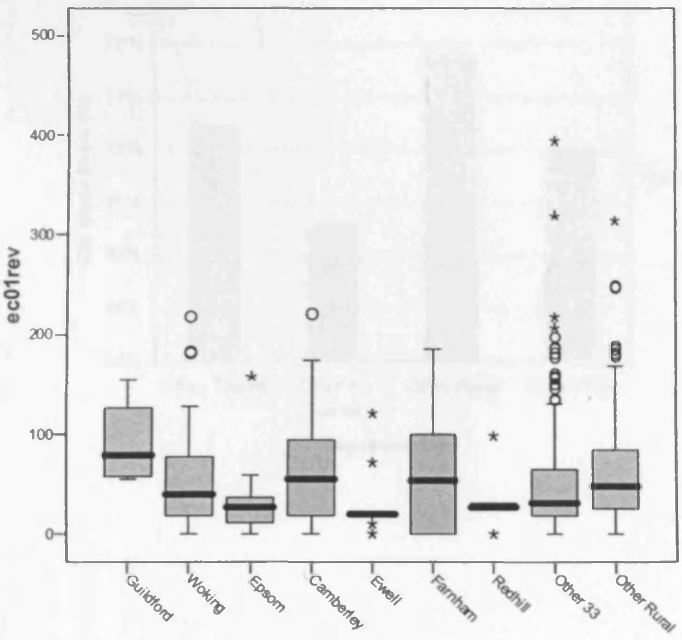


Figure 4.13: *Resident Settlement Size and Energy Consumption*

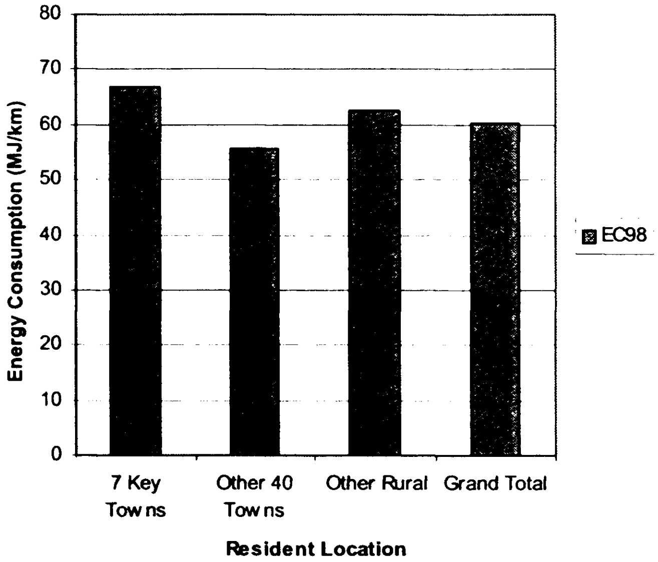
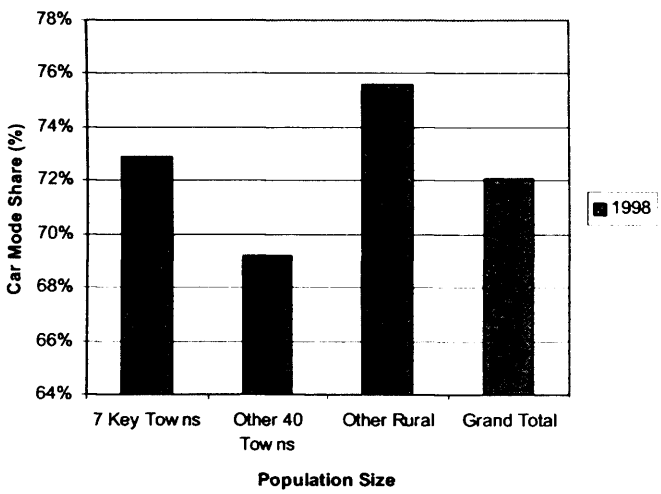


Figure 4.14: *Resident Settlement Size and Car Mode Share*



Workplace Settlement Size

As an interesting comparison, we show below travel behaviour by workplace settlement size.

Table 4.9: *Workplace Settlement Size and Travel Behaviour*

Town/Area	Settlement Size		Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver		% Train	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Inner London	-	2,765,975	325	99	50.6	65.1	58.1	54.9	96.4	90.1	19%	20%	75%	75%
Outer London	-	4,406,061	384	76	74.2	58.8	28.0	22.5	36.2	31.9	84%	83%	6%	9%
7 Key Towns (sub total)	291,970	296,432	237	84	36.1	36.8	11.7	16.9	18.1	25.4	80%	82%	2%	3%
Guildford	64,681	65,782	53	16*	45.1	55.0	15.5	23.8*	17.9	29.5*	88%	82%*	0%	6%*
Woking	56,422	56,059	70	24	30.1	28.8	9.3	18.5	13.8	25.4	74%	84%	1%	0%
Ewell	38,647	38,569	5**	1**	28.6	72.7	9.9**	25.3**	16.6**	42.5**	100%**	83%**	0%**	0%**
Farnham	36,289	35,924	11*	6**	37.6	29.2	10.7*	12.1**	15.2*	17.6**	58%*	90%**	0%*	0%**
Camberley	34,949	36,171	32	10*	30.2	23.3	8.8	14.5*	13.8	27.6*	73%	100%*	3%*	0%*
Redhill	31,892	32,654	33	15*	33.6	16.6	11.7	11.5*	32.6	26.4*	82%	71%*	6%*	13%*
Epsom	29,090	31,273	33	12*	42.8	50.5	13.8	15.2*	18.4	19.6*	66%	73%*	0%*	0%*
Other 33 Towns (all below 25,000 population threshold size)	-	-	320	92	42.9	43.1	14.5	16.4	18.5	21.0	85%	87%	1%	1%
Other Rural (wards not within 40 Surrey towns)	-	-	107	55	39.8	47.5	13.2	18.6	17.9	23.5	86%	82%	2%	2%
Other Adjacent Counties	-	-	261	78	83.4	70.0	37.0	34.9	39.9	40.5	90%	91%	2%	1%
Grand Total (Surrey population)	1,037,000	1,047,750	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%	17%	18%

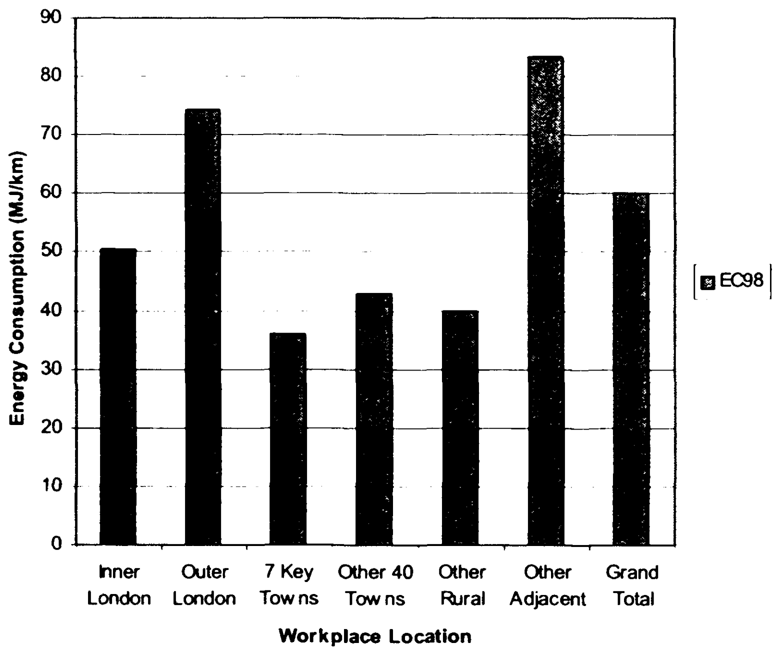
Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

Y: 5% < sample average

Figure 4.15: *Workplace Settlement Size and Energy Consumption*



Again the observed travel behaviour varies hugely between the different workplace locations.

- Respondents are fairly well spread between the different workplaces. Inner London (20% of the sample in 1998, 19% in 2001) and Outer London (23% in 1998, dropping to 14% in 2001) are very important workplace locations; as are the smaller towns (19% in 1998 and 18% in 2001), adjacent counties (16% in 1998 and 15% in 2001) and other rural areas (6% in 1998 rising to 15% in 2001).

- There is not an apparent inverse linear relationship with workplace settlement size and travel behaviour. But there are a number of interesting patterns:

  - Journeys to workplaces in Inner London are a very distinct cohort: lengthy (an average of 58 km in 1998) and dominated by train mode share (75%). Energy consumption per capita is not huge because of the high rail occupancy assumed in the AM peak (leading to an average commute energy consumption of 51 MJ/jtw in 1998).

  - Outer London is associated with shorter distances (an average of 28 km in 1998) but high car dependency (84%), hence relatively high energy consumption (74 MJ/jtw). Other adjacent counties are similar; but with longer distances (an average of 37 km), higher car dependency (90%) and higher energy consumption (83 MJ/jtw).

  - Commutes to the major 7 towns in Surrey are much shorter in distance (an average of 12 km in 1998) and hence less energy consuming (36 MJ/jtw).

These are interesting results: the implication being that concentrating employment centres within the 7 key towns or other towns in Surrey, or in Central London, would help reduce energy consumption in the journey to work.

In terms of strength of relationships, chi-square analysis confirms that there is no significant relationship between workplace population size and travel behaviour.

Table 4.15B: *Workplace Population Size and Travel Behaviour*

Chi-Square Test	Value	df	Asymp. Sig. (2-sided)
Workplace population size-EC98			
Pearson Chi-Square	18.011	16	0.323
Likelihood Ratio	18.301	16	0.307
Linear-by-Linear Association	1.273	1	0.259
a 0 cells (0%) have expected count less than 5. The minimum expected count is 1.92.			

N = 1,653 in 1998

***Correlation is significant at the 0.01 level (2-tailed)*

**Correlation is significant at the 0.05 level (2-tailed)*

Settlement Size, Potential Socio-Economic Influences and Travel Behaviour

Socio-economic characteristics are also likely to play an important role in influencing travel behaviour and below we attempt to take an initial look at the effect of household income on the population size and travel behaviour relationship.

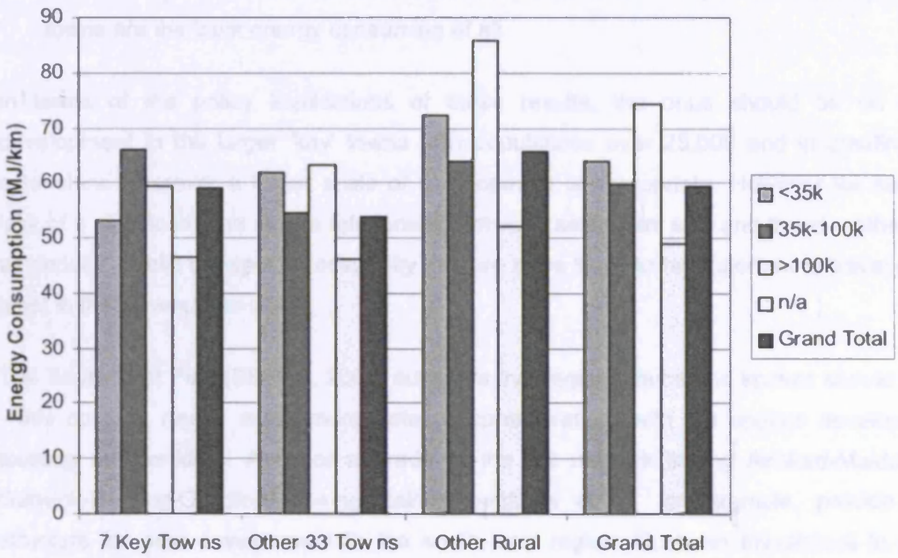
Table 4.10: *Settlement Size, Household Income and Energy Consumption (MJ/jtw)*

Resident Settlement Size	Household Income 2001									
	< £35k		£35-£100k		> £100k		Not Stated		Total	
	Count	MJ/jtw	Count	MJ/jtw	Count	MJ/jtw	Count	MJ/jtw	Count	MJ/jtw
7 Key Towns	14*	53.2	50	[redacted]	15*	59.4	21	46.7	100	58.9
Other 33 Towns	35	61.8	121	54.5	10*	63.2	59	46.2	225	54.0
Other Rural	30	[redacted]	91	63.9	30	[redacted]	49	52.0	200	[redacted]
Grand Total	79	64.0	262	59.8	55	74.4	129	48.9	525	59.4

Data: Surrey New Occupiers Survey 2001. Income data was not available from the 1998 survey (NB. Sample size: *<20, **<10 respondents)

Clearly because of the sample sizes in some of the cohorts it is difficult to make firm conclusions. Energy consumption however appears higher with the highest household incomes; household incomes over £100k consume on average over 25% MJ/trip more than the sample average.

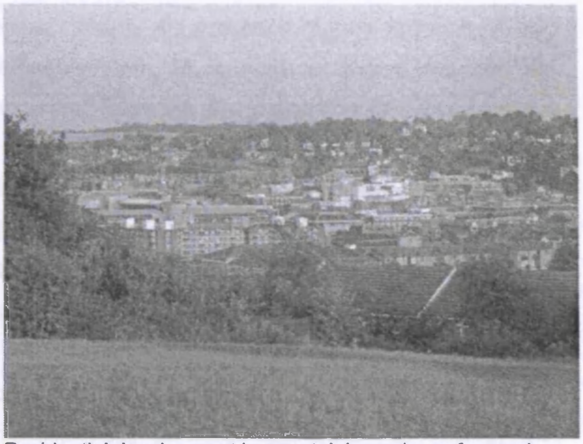
Figure 4.14: *Settlement Size, Household Income and Energy Consumption (MJ/jtw)*



We might expect the smaller sized areas, particularly the 'other rural' category, to be more energy consuming than the larger sized areas across all income bands. This does appear within the Surrey data.

Settlement size: summary thoughts

What has been learnt in terms of settlement size and travel behaviour? Again the analysis in this thesis benefits from being wide ranging (using different definitions of settlement size and travel behaviour) and in using the urban/rural fringe location as the empirical research area. The following issues are important:



Residential development has certainly not been focused on the major towns in Surrey, a 'pepper-potting' approach is more evident, meaning that, at times, there is little strategic sense to housing allocations over time. New housing located in settlements with populations below 25,000 is, for example, associated with high energy consumption in travel patterns (View from Stag Hill, Guildford).

- New household growth (in 1998 and 2001) has not been focused in the major towns in Surrey.

- There is not a direct inverse relationship between resident settlement size and travel behaviour. Within the 25,000-50,000 population range there is considerable difference in behaviour. For example, Redhill, Epsom and Ewell are associated with the smallest average energy consumption patterns, mainly due to their short journey to work lengths. Camberley and Farnham have higher energy consumption patterns, potentially due to their remote locations and/or proximity to relatively uncongested road networks.

- Although there is no significant relationship between workplace settlement size and travel behaviour, journeys to workplaces in Inner London are a very distinctive cohort, with lengthy trips, mainly by public transport. Trips to Outer London are shorter in length but more car dependent. Trips to other adjacent counties are longer in distance, with very high car dependency. Both are therefore high enery consumers. Trips within Surrey to the major 7 towns are the least energy consuming of all.

In terms of the policy implications of these results, the onus should be on concentrating development in the larger 'key' towns with populations over 25,000 and in creating sustainable extensions wherever a larger scale of development is appropriate. However we should note the lack of a significant and simple relationship between settlement size and travel – other factors such as density, public transport accessibility etc. are more likely to be important to travel generation (at least in the commute to work).

The South East Plan (SEERA, 2005) suggests that regional hubs and spokes should be developed - this concept needs much more detailed consideration, with the spokes developed along the existing rail corridors. A major upgrade of the rail network linking Ashford-Maidstone-Reigate-Gatwick-Dorking-Guildford-Woking-Staines-Heathrow could, for example, provide the defining structure for new development in the south east region. Such an investment in an integrated manner - linking transport to development - would enable the region to accommodate increased housing and employment growth. At the moment the counties are taking a NIMBY stance, many would argue, and refusing higher levels of development. Strategic urban and regional planning is thus not as developed as it could or should be.

An important side issue: clearly linked to settlement size is the provision of local facilities. Good local provision, perhaps associated with larger settlements, or at least not associated with the smallest settlements, may reduce travel distance and increase the proportion of short journeys capable of being carried out by non-motorised modes. Although we provide no assessment of local facility provision in Surrey in this thesis, it is still interesting to consider other research on this topic. For example, proximity analysis in Gloucestershire (Williams, 1998) shows that small, more isolated settlements have fewer and less diverse facilities and services. This lack of provision encourages longer journey lengths and greater use of the car, particularly where public transport links are poor. This seems to be reflected, intuitively at least, in the Surrey data: the least energy consuming trips in Surrey are those to workplaces in the 7 major towns. To apply the thinking of Jenks et al (1997): a strategy of polycentric decentralised concentration may be most appropriate for Surrey; with growth concentrated in a selected number of the major towns; and local services, facilities and employment opportunities encouraged.

4.1.3 Distance from the Urban Centres and Transport Networks

Another 'well-researched' land use variable covers location in terms of distance from the urban centre, and less so, the transport network. In much of the research, increasing distance from home to the urban centre is associated with increasing travel distance, an increasing proportion of car journeys and increasing transport energy consumption. Trip frequency does not, however, seem to vary significantly according to distance between home and urban centre. Below we outline a number of the more important research findings.

Spence and Frost (1995) describe the changes in commuting distance between 1971 and 1981 in London, Manchester and Birmingham. They show change according to distance between home and urban centre:

- London - commuting distance increases almost linearly with distance between home and centre.

- Birmingham - commuting distance first increases with increasing distance between home and urban centre. A plateau is reached at around seven kilometres from the urban centre, and then at around nine kilometres from the centre, commuting distance actually begins to decrease as distance from the urban centre increases.

- Manchester - as in Birmingham, commuting distance first increases with increasing distance from the urban centre. At around five kilometres from the centre, a plateau is reached in commuting distance. There is no change with further increases from the city centre.

Mogridge (1985) also demonstrates a linear relationship between distance from home to the centre and transport energy consumption. The relationship is shown to be very similar in both London and Paris. On average, residents living at a distance of 15 kilometres from the urban centre consume more than twice the transport energy consumed by residents living five kilometres from the urban centre.

Similarly, Newman and Kenworthy (1988) identify the relationship between transport energy consumption and the distance from the central business district in Perth. They demonstrate a linear relationship, although not as steep. Residents living 15 kilometres from the central business district, consume approximately 20 percent more transport energy than residents living five kilometres away.

Naess (1996) identifies a statistical relationship between the distance from the urban centre and travel distance per person in Oslo, where total distance increases with increased distance between home and urban centre. They examine the effect of distance from home to urban centre on transport energy consumption - with conclusions showing energy consumption increases as distance increases. A causal model was constructed containing a variety of land use and socio-economic variables, showing how car ownership had the greatest influence on transport energy consumption, followed by distance between home and urban centre, accessibility to local facilities from the home, income per capita, and then various other socio-economic factors.

Similar relationships have been found using data from around the UK. Banister (1992) compared settlements in Oxfordshire, based on data from 1978. He demonstrated that the largest settlement in the area, with the most facilities and the best public transport (and the highest density), was the most energy efficient, and exhibited the highest share of walk trips. The least efficient was the most remote village. Amongst the other settlements, dormitory villages were found to be particularly inefficient.

Again in Oxfordshire, Curtis and Headicar (1995) show a number of trends:

- Distance between home and urban centre may be linked to average work journey distance - average work journey distance is lowest in the two locations closest to the centre of Oxford (Botley and Kidlington) and highest in the two locations furthest from the centre (Bicester and Witney).

- A link between average non-work journey distance, and distance from home to urban centre is much less apparent - average travel distance is highest in Witney, Bicester and Botley, the first two locations being most distant from the city centre and the latter the closest. The lowest average non-work travel distance was recorded in Kiddlington (close to the centre of Oxford).

- The frequency of both work and non-work journeys does not vary significantly according to distance between home and the urban centre.

- The proportion of journeys by car may be related to the distance between home and city centre - the mode share of car journeys being highest in the two locations furthest from the city centre, and lowest in the two locations closest to the centre.

The findings on distance from urban centre from Gordon et al (1989) are this time more consistent with the 'mainstream' research. Describing average travel distance in the US between 1977 and 1983, comparing people residing in and outside of cities and for various sizes of city, journey distances for both work and non-work journeys were almost always lower for residents inside cities than those outside.

A further variation on the location theme comes from Headicar (1997). He considers the impact of proximity to the transport network on travel behaviour, using survey data from Oxfordshire. Better access to transport networks, particularly road and rail networks, appears to increase travel speeds and extends the distance that can be covered in a fixed time. Major transport networks can therefore be a powerful influence on the dispersal of development; residential and employment. Proximity to major transport networks may lead to travel patterns characterised by long travel distances and high transport energy consumption. Headicar (1997) particularly looks at the effect of strategic transport routes. The research was carried out in Oxfordshire, close to the M40 (one of the few motorways in the UK that is not very-well used, thus allowing long commuting journeys). The research results show how the location of developments close to a strategic transport route has a distorting effect in increasing the proportion of very long commuting journeys. It also biases the mode share towards the route concerned. Together this has the effect that development at a freestanding town, close to a national motorway is associated with exceptionally high car mileage per head. An equivalent location close to a strategic rail station has a 'counterveiling' effect, but on a more modest scale overall.

Also interesting in Oxfordshire is the extent of town self-containment. Overall less than one in five work journeys from new developments are to places within the same settlement. For non-work journeys (those made regularly) the proportion is just under a half. As might be expected the settlements near the edge of the principal city (Oxford) have somewhat lower levels of self containment themselves, but in terms of travel effects this is more than offset by their links with the principal city. Significantly in the expanding freestanding towns, more than a quarter of all work journeys are to places outside the county altogether.

So, **in summary**, the key issues for this thesis, in terms of distance from urban centres and transport networks are as follows:

- Distance from London: does commuting distance increase linearly with distance from London, in accord with the Spence and Frost (1995) research? What happens to energy consumption, journey time and mode share? Is a plateau reached at any point? How much further do residents living further away from London commute?

- Does proximity to the road transport network extend travel distances and bias mode share?

EVIDENCE FROM SURREY: DISTANCE FROM LONDON AND HIGHWAY NETWORKS AND TRAVEL BEHAVIOUR

Distance from London is shown using distance isochrones overleaf. NB. Centre Point (on the corner of Tottenham Court Road/Oxford Street) is taken as the nominal centre point of London in the analysis.

Figure 4.17: *Distance from London*

Table 4.11A shows distance from London and average energy consumption, journey to work distance, journey to work time and mode share in 1998 and 2001.

Table 4.11A: *Distance from London and Travel Behaviour*

Distance from London	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver		% Train	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
20-30 km	226	72	42.4	40.1	21.5	21.1	35.6	42.4	72%	59%	18%	22%
30-40 km	669	199	54.2	52.8	29.2	28.2	43.1	43.1	68%	61%	20%	22%
40-50 km	426	154	64.2	67.4	32.3	30.5	44.1	41.3	73%	76%	16%	15%
50-60 km	212	54	78.4	71.2	35.3	33.7	41.8	41.6	79%	80%	10%	13%
> 60 km	120	46	80.8	74.9	35.3	39.7	42.9	51.5	79%	85%	7%	4%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%	17%	16%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

Y: 5% < sample average

In terms of distribution, the majority of households are located either 30-40km or 40-50km from London. Again the Surrey analysis is concerned with the diferent travel behaviour variables and the urban/rural fringe location considered. Trends in the data are summarised below:

- There appears to be a clear relationship between residential distance from London and energy consumption. These findings are similar to those of Newman and Kenworthy (in Perth, WA; 1988) and Spence and Frost (in London, Birmingham and Manchester; 1995).

- As distance increases, average journey to work energy consumption increases; there appears to be no plateau. For example, in 1998 residents living over 60 km from London consume on average 91% more energy in the journey to work trips than residents living 20-30 km from London.

- Both journey to work distance and mode share contribute to these trends: in 1998 resident locations >50 km from London experience 64% lengthier average journey lengths than those living 20-30 km from London. Journey time interestingly stays relatively constant: at around the 35-45 minutes range.

- Car mode share correspondingly increases with distance from London. This is again similar to the trends identified by Mogridge (in London and Paris; 1985), Newman & Kenworthy (in Perth, Western Australia; 1988) and Naess (in Oslo; 1996).

Correlation analysis supports these conclusions – there is a very strong positive relationship between distance from London and energy consumption and journey distance.

Table 4.11B: *Distance from London and Travel Behaviour*

Land Use Variable	Correlation	EC98	EC01	JD98	JD01
distlon	Pearson Correlation	0.179**	0.211**	0.143**	0.14**
	Sig. (2-tailed)	0.000	0.000	0.000	0.001

***Correlation is significant at the 0.01 level (2-tailed)*

**Correlation is significant at the 0.05 level (2-tailed)*

The following figures summarise this data in terms of distance from London cohort and energy consumption and mode share.

Figure 4.18: *Distance from London and Energy Consumption 1998*

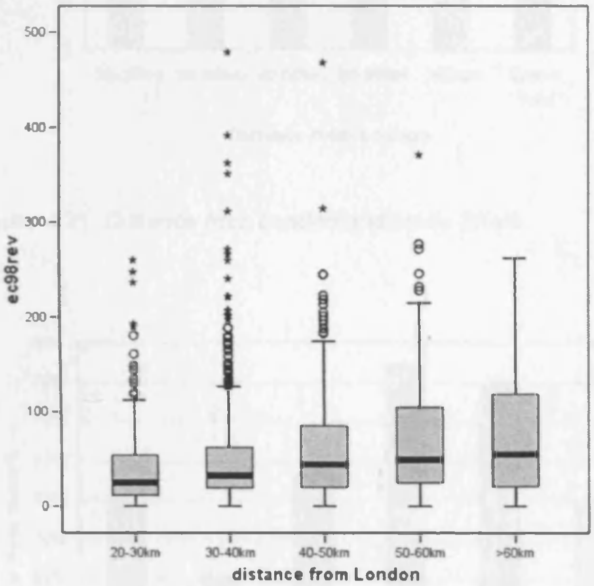


Figure 4.19: *Distance from London and Energy Consumption 2001*

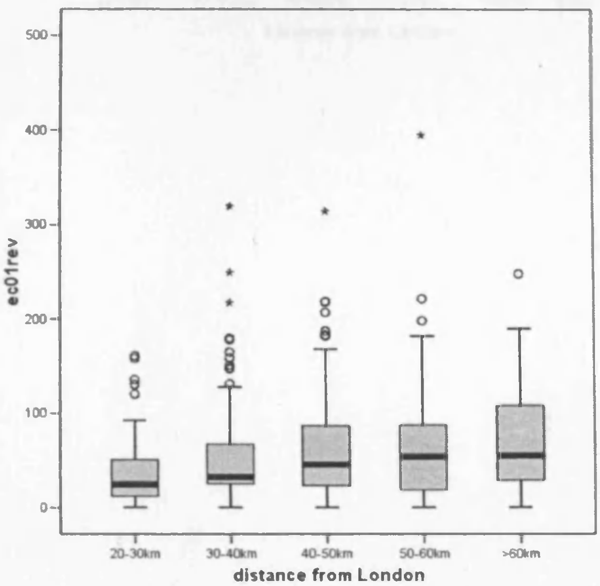


Figure 4.20: *Distance from London and Energy Consumption*

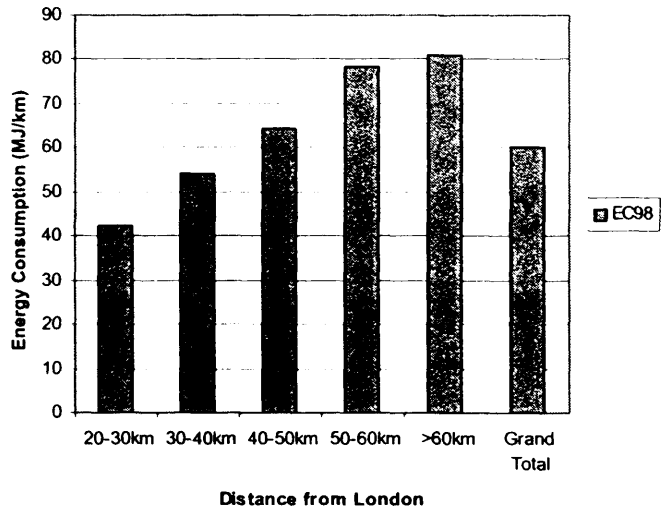
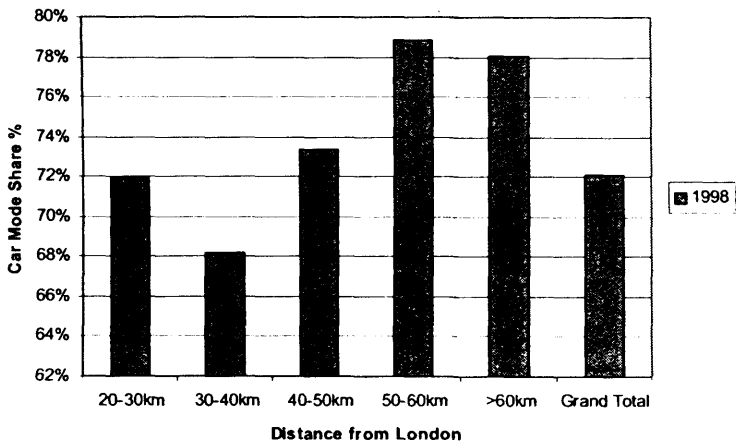


Figure 4.21: *Distance from London and Mode Share*



Distance from strategic highway network in Surrey

A further key factor in distance/location terms may be the influence of the motorway and main road network. Distance from the key highway routes in Surrey – the M25/M3/A3/A31 – is shown using distance isochrones in Figure 4.22 (NB. the influence of public transport accessibility is considered in a later section of the thesis, see Page 142). The isochrone distance used is 3km distance from the highway network.

Figure 4.22: *Distance from Key Highway Networks (M25/M3/A3/A31)*

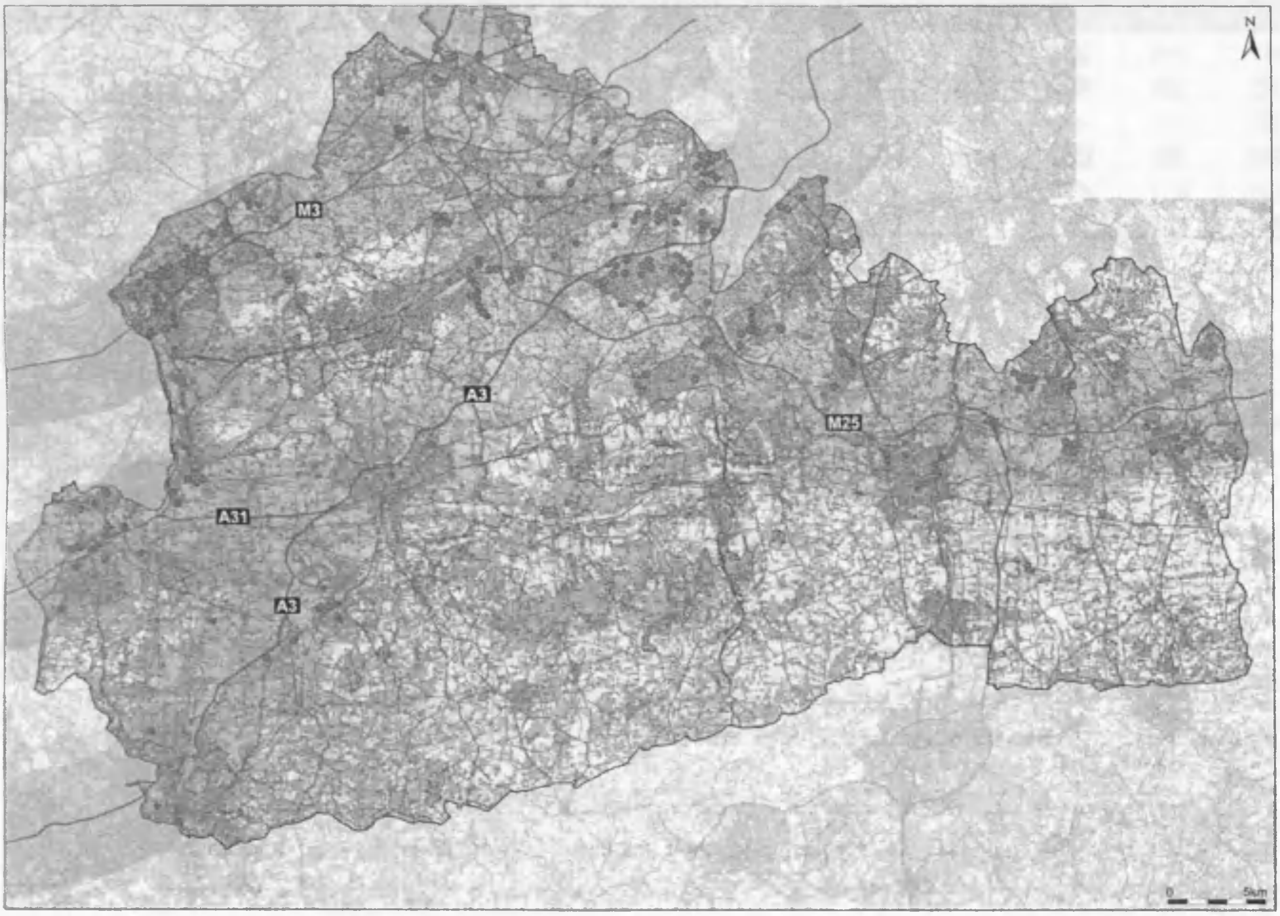


Table 4.12A shows household location in relation to the strategic road network (within a 3km catchment) and average energy consumption, journey to work distance, journey to work time and mode share. The following figures summarise the results graphically.

Table 4.12A: *Household Location Relative to the Strategic Road Network and Travel Behaviour*

Within 3km Catchment of Strategic Route Network	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver		% Train	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
M25	465	150	59.3	53.9	30.9	28.0	43.5	41.7	71%	62%	20%	19%
M3	173	39	78.4	67.8	33.4	27.4	39.6	33.6	80%	76%	9%	7%
A3	148	29	54.1	58.6	28.9	25.3	42.9	39.8	72%	68%	18%	8%
A31	136	48	78.1	74.3	35.3	37.6	41.3	46.7	81%	75%	9%	11%
None	731	259	54.3	58.5	28.1	28.7	41.5	41.5	70%	69%	17%	19%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%	17%	16%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

Y: 5% < sample average

In terms of distribution, the majority of households are not located within a 3km catchment of the strategic route network. Importantly, however, a large number are close to the M25 (28% in 1998 and 29% in 2001); M3 (10% in 1998 and 7% in 2001); A3 (9% in 1998 and 6% in 2001); A31 (8% in 1998 and 9% in 2001). There is a clear relationship between household location and distance from the strategic road network and energy consumption. Trends in the data are summarised below:

- There appears to be a clear relationship between distance from the highway network and energy consumption. These findings are similar to those from Headicar (1995 and 2000), but provide findings at a different scale - at the county-wide level and for new households.

- All households located close to the strategic highway network are associated with high average journey to work energy consumption. Those located further away from the highway network have lower energy consumption figures. The M3 and A31 are associated with the highest average energy consumption: possibly because these are relatively uncongested routes and allow high commute distances over relatively short journey times. For example, in 1998 residents living within 3km of the M3 consume on average 44% more energy in journey to work trips than residents living over 3km away from the strategic highway network. Similar figures are evident for residents located close to the M25 (9% more than residents living over 3km away) and the A31 (44% more than residents living over 3km away). Both journey to work distance and mode share contribute to these trends. Journey time stays more constant: at around the 40-45 minutes range.

Chi-square analysis confirms these findings – there is a significant relationship between energy consumption and distance from the strategic road network, in both 1998 and 2001.

Table 4.12B: *Household Location Relative to the Strategic Road Network and Travel Behaviour*

Chi-Square Test	Value	df	Asymp. Sig. (2-sided)
Distance from Highway-EC98			
Pearson Chi-Square	91.02 [a]	15	0.000**
[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 11.72.			
Distance from Highway-EC01			
Pearson Chi-Square	15.39 [b]	6	0.017*
[b] 0 cells (0%) have expected count less than 5. The minimum expected count is 7.21.			

***Chi-square is significant at the 0.01 level*

**Chi-square is significant at the 0.05 level*

Figure 4.23: *Distance from Strategic Road Network and Energy Consumption 1998*

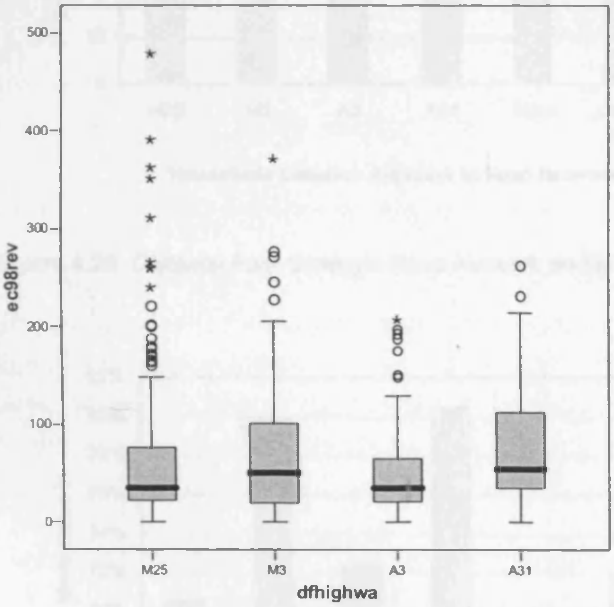


Figure 4.24: *Distance from Strategic Road Network and Energy Consumption 2001*

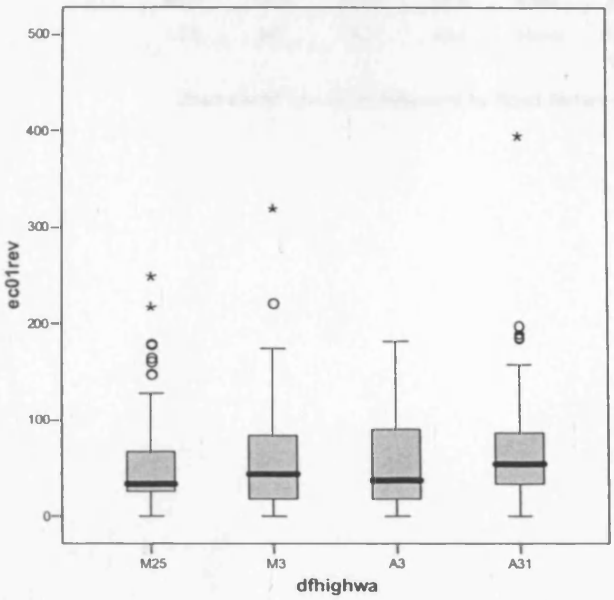


Figure 4.25: *Distance from Strategic Road Network and Energy Consumption*

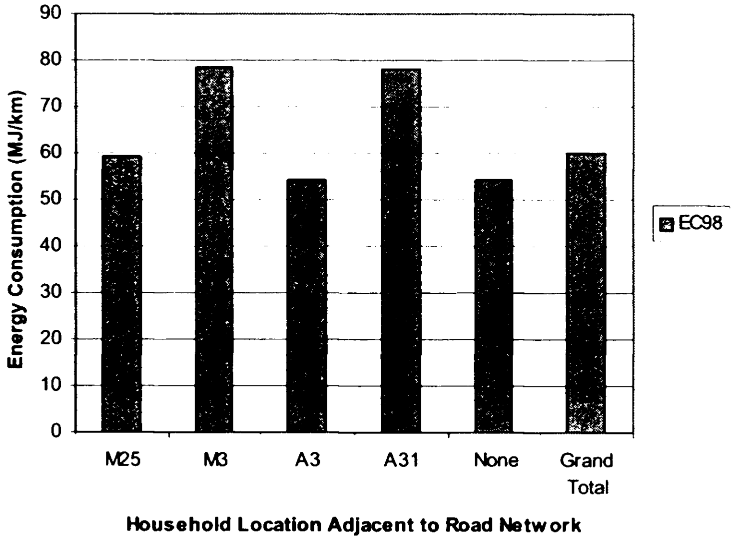
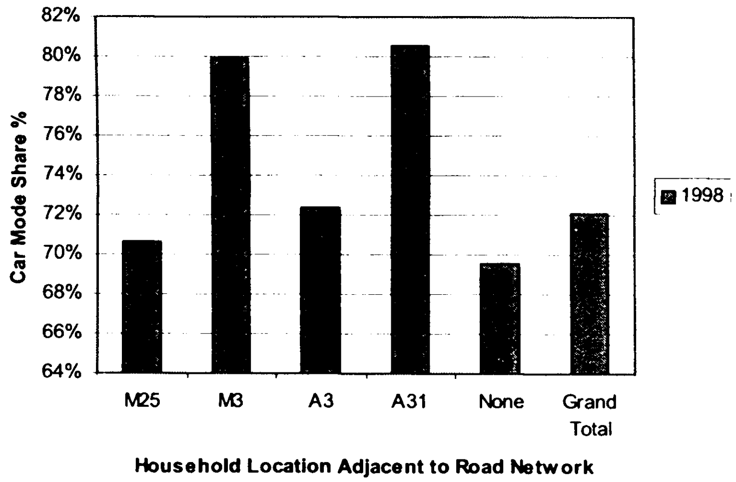
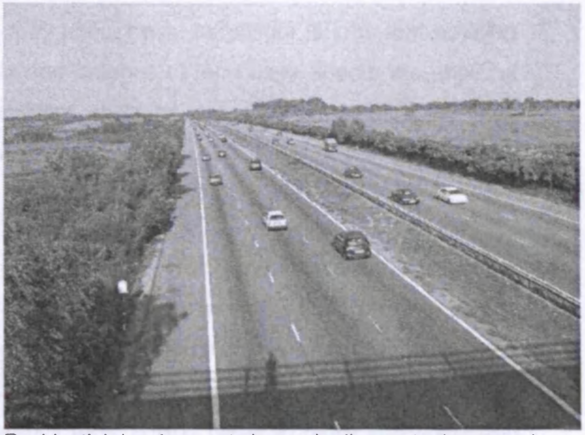


Figure 4.26: *Distance from Strategic Road Network and Mode Share*



Distance from London, major urban areas and the highway network: summary thoughts



Residential developments located adjacent to the stategic highway network are associated with high car dependency and above average energy consumption patterns in the commute to work (M3, near Frimley, Surrey Heath).

The evidence appears to be giving a consistent storyline: increased household distance from London and household location close to the strategic highway network is associated with high energy consumption in the commute to work.

The distance from London results confirm those by Spence and Frost (1995), Newman and Kenworthy (1988) and Naess (1993). It appears that the influence of London on Surrey is such that, as households are located further away, the public transport offer becomes less attractive, hence is used less and less. The road network becomes less congested, and is used more and more.

The results showing distance from the strategic highway network and travel behaviour are similar to Headicar and Curtis (1994); and Headicar (1995 and 2000), although measured in this thesis in terms of energy consumption, commute distance, time and mode share; and at a greater aggregate level. Households located adjacent to the strategic highway network - and particularly a free-flowing highway network - are associated with greater energy consumption in the commute to work, and increasingly so over time.

Hence at the local level there is much greater variation in commuting behaviour relative to distance from the urban area and strategic highway than might be expected. PPG13 doesn't recognise this distinction (and indeed possibly shouldn't). However, this is a critical contextual issue for Regional Spatial Strategies, Regional Transport Strategies, Local Development Frameworks and Local Transport Plans. It is here that a clear policy direction needs to be defined as to *which* (urban) areas are the optimum locations for new housing development. It is only through a micro analysis of the trends that we can make progress here. Without this local plan making becomes repetitive of the national stance and offers little new.

4.1.4 Job and Housing Balance

The final 'well-researched' land use feature which may affect travel behaviour is jobs and housing balance: the conventional thesis being that the mix and balance of land uses affects the physical separation of activities and is therefore a determinant of travel demand. Much of the recent research on this topic has been USA-based; Cervero (for example, 1985, 1989a and 1996a) has written widely.

In the UK jobs and housing balance has gained less attention. The New Towns have been the subject of some analysis (Thomas, 1969; and Breheny, 1990); these settlements were originally and purposively designed to be self-contained and balanced. Thomas created an 'independence index' which was a ratio of internal work trips (intra-commuting) divided by the sum of in and out trips (external commuting). Thomas found that Mark I New Towns became more self-contained over the 1960s. Breheny showed that this self-containment had declined, though the newest generation of New Towns had maintained relatively high levels of self-containment. The current nearest discussion is concerned with promoting 'mixed use'. PPG3 (DETR, 2000) for example states that "local planning authorities should encourage the development of mixed and balanced communities: they should ensure that new housing developments help to secure a better social mix by avoiding the creation of large areas of housing of similar characteristics."

Some research suggests that mixing of land uses is not as important as density in influencing travel demand (Owens, 1986; ECOTEC, 1993). However there have been few systematic attempts to consider jobs and housing balance and its relationship with travel behaviour. Guidance from the UK national government has, to some extent, taken mixed use as a 'given' positive desired state. For example, Llewelyn-Davies for DETR (2000) consider the obstacles to implementation rather than providing evidence behind the policy concept.

In the USA, the mixing of land uses is commonly measured using job ratios, and usually the ratio of jobs in the area to workers resident in that area. A 'balanced' community is generally thought of as a self-contained, self-reliant one, within which people live, work, shop and recreate (Burby et al, 1976). Margolis (1973) adopted the rule of thumb that communities are balanced when the ratio of jobs to housing units lies within the range of 0.75 to 1.25. The benefits from more balanced job and housing growth may include shortened commute distances, an increased share of non-motorised trips and reduced traffic volumes and energy consumption across the region. In addition, jobs-housing balance may promote wider social objectives. For example, the provision of affordable housing closer to suburban job centres would improve the residential opportunities of lower income groups, potentially reducing housing discrimination.

Cervero has, over the last 20 years, as well as other research topics, looked in detail at the issue of job-housing balance in the San Francisco region. Cervero (1989a) describes the various waves of suburbanisation in the USA. The first wave involved the steady flow of residents to the outskirts of cities over the past century. This was followed by the second wave – the migration of retail activities to the suburbs, epitomised by the opening of large indoor shopping malls in the 1950s and 1960s. The 1980s witnessed the third wave of suburbanisation – the mass arrival of jobs, in particular white-collar office and service jobs to the suburbs (Orski, 1986). This third wave, highlighted by the emergence of business parks and office towers, has fundamentally changed the face of suburbia in the USA. No longer are they simply origins of commuter trips each weekday morning. They are major destinations as well.

The balanced community ratio of 0.75 to 1.25[30] is important in that any jobs-housing ratio above this figure suggests that there is an insufficient supply of available housing to meet the needs of the local workforce. The result would be a predominant pattern of in-commuting of workers in the morning and out-commuting in the evening. The reverse would also be presumably true: lower than this optimum ratio and there would be an insufficient supply of employment to meet the needs of the local residents.

Cervero (1989a) reports that many of the fastest growing suburban communities on the San-Francisco region have jobs-housing ratios that far exceed the 1.5 threshold. For example Silicon Valley – the communities of Santa Clara, Sunnyvale and Palo Alto – all have ratios above 2.5. Others such as Midtown and Perimeter Centre have more than 5 times as many jobs as housing units. Cervero speculates, reflecting the thoughts of Gordon and Richardson (1989a), that one benefit that might be expected from the relocation of jobs to the suburbs is a shortening of journeys to work and, correspondingly, an overall improvement in regional traffic conditions. He concludes, however, that this has not been the happened. For the USA as a whole, and work trips made wholly within the suburbs - the fastest growing commuter market - actually increased in length by around 15% during the 1970s. From 1977 to 1983, the mean journey to work for suburban Americans (people residing outside a central city but within the urbanised area) increased from 10.6 miles in length to 11.1 miles, despite the mass migration of jobs to the suburbs during this period. Evidently then, more suburbanites are further from their workplaces today than a decade or more ago when the preponderance of jobs were confined to inner cities.

Part of the reason for this continuing lengthening of commuter trips, Cervero believes, is the widening job-housing imbalance in many metropolitan areas across the USA. The spatial mismatch between the location of jobs and the location of (affordable) housing is forcing people to reside further from their workplaces than they would otherwise choose. The result is increasing traffic volumes and increasing congestion.

Cervero's (1989a) analysis interestingly shows that, for some communities with approximate balance – such as San Francisco and Santa Rosa – a majority of residents worked in their home community. However, in others – such as Mountain View and Walnut Creek – jobs and housing were broadly in balance, yet fewer than 20% of workers resided locally. Thus suggesting that balance requires more than numerical parity, such as concordance in worker earnings and local house prices, employment type and resident skill levels, etc. Imbalances may also increasingly reflect issues of choice, more than simple barriers to movement. Cervero goes on to report a negative relationship between job ratio and the proportion of journeys undertaken by foot and cycle - where there are many more jobs than houses, the proportion of journeys by foot or cycle falls. Cervero concedes that the statistical relationship is not very strong, but suggests that encouraging a balance of houses and jobs may encourage walking and cycling.

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[30] Cervero (1989a) extends this optimum balance figure to 0.75-1.5 to reflect the recent increase in the female workforce.

Ewing et al (1995a) similarly investigate the effect of various land use characteristics, including the balance of homes and jobs and journey frequency. Giuliano and Small (1993) in a study of commuting patterns in San Francisco, question the importance of job ratio on travel patterns. They present the results of a commuting study in the Los Angeles region to show that job ratio has a statistically significant, but relatively small, influence on commuting time. They conclude that attempts to alter the metropolitan structure of land use are likely to have small impacts on commuting patterns, even if jobs and housing became more balanced. Banister et al (1997a), on the other hand, identify a relationship between job ratio and energy use per trip in one of their case studies in Oxford.

Recently there has been some debate over the most effective measurement of jobs/housing balance. Two methods are most frequently used:

- Net effects: resident jobs/households

- Dynamic effects: resident and working in area/resident and working outside area

The former suffers to a certain extent in that a theoretical balance may be apparent, however all the resident population may work elsewhere and be replaced by the same number of workers commuting in. The attempt to capture dynamic effects overcomes this, however is more difficult to assess because of limited data availability.

So, **in summary**, from the relatively few case studies to have examined the effect of job ratio on travel patterns, the evidence still appears to be unclear. Again one of the reasons may be definitional, in that different measures/surveys of travel patterns are used, for example mode share (Cervero, 1989a), travel time (Giuliano and Small, 1993) and transport energy use (Banister, 1997a).

The key issues for this thesis, in terms of jobs and housing balance are as follows:

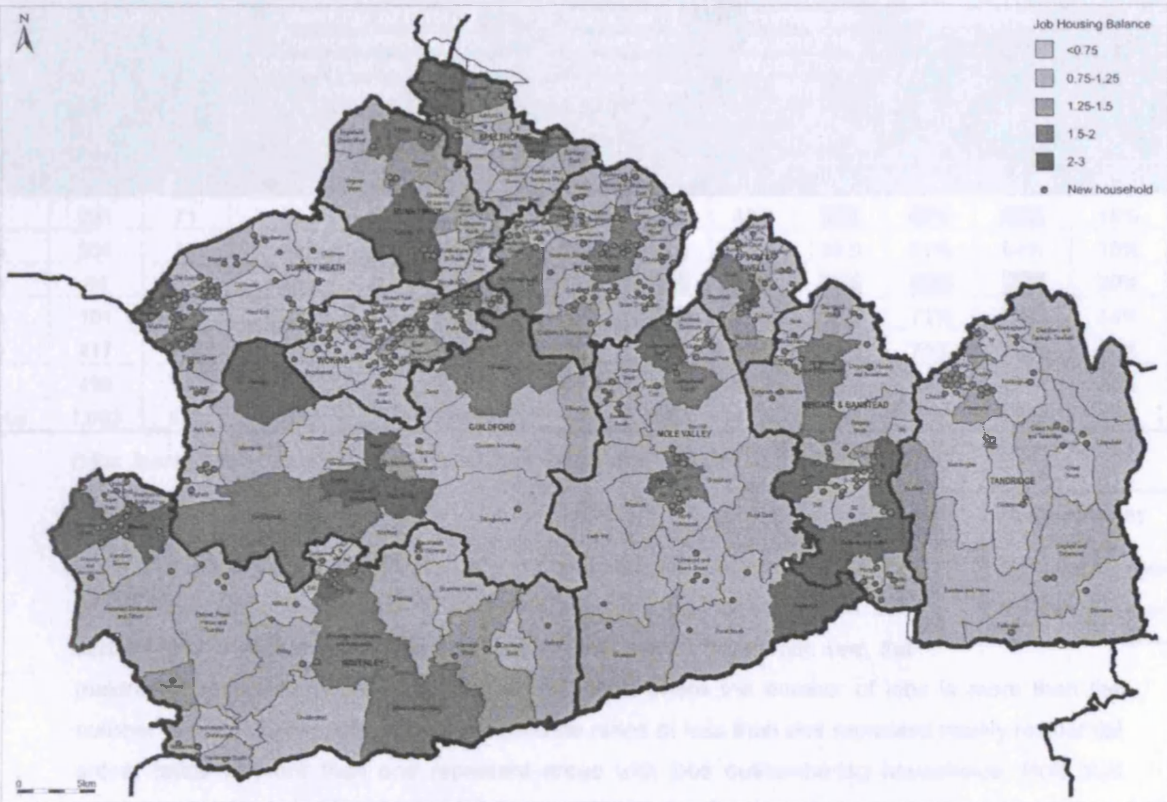
- Do balanced communities – with resident jobs/household ratios between 0.75 and 1.5 – reduce energy consumption in the journey to work, and encourage shorter trips and times and less car usage (developing the thoughts of Cervero, 1989a and 1996)? Or is theoretical balance irrelevant: do people still tend to 'choose' an employment opportunity beyond the supposed balanced community?

- Where there are many more jobs than houses, does the propensity to use non-car modes fall? What happens in the traditional dormitory settlement where there are many more houses than jobs?

EVIDENCE FROM SURREY: JOBS-HOUSING BALANCE AND TRAVEL BEHAVIOUR

Net resident jobs-household ratios are shown by ward in Surrey in Figure 4.25. The following sections analyse the data first in aggregate (Surrey-wide) and then, in more detail, by jobs housing balance cohort.

Figure 4.27: *Net Resident Jobs-Household Ratios in Surrey*



Surrey-wide: aggregate analysis

Table 4.13 shows net jobs-household balance data for Surrey as a whole in terms of workplace jobs, resident households and jobs/household ratio. The county, as a whole, lies comfortably within the suggested 0.75-1.5 jobs-household balance range. Jobs-housing balance is of course easier to achieve at a larger geographical scale, and analysis at this level misses the kurtosis effects - changes at the micro scale.

Table 4.13: *Net Jobs and Household Balance in Surrey*

	Workplace Jobs			Resident Households			Jobs-Household Ratio		
	1998	2001	% Change	1998	2001	% Change	1998	2001	% Change
Surrey	464,400	487,102	+5%	399,923	433,176	+8%	1.16	1.12	-4%

Net Effects

Table 4.14A shows net resident jobs-household ratios and average energy consumption, journey to work distance, journey to work time and mode share for the new household occupiers sample in 1998 and 2001.

Table 4.14A: *Net Jobs and Household Balance*[31] *and Travel Behaviour*

Jobs-Household Balance	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver		% Train	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
<0.75	221	71	62.3	54.6	30.9	25.6	42.0	36.7	66%	60%	18%	15%
0.75-1.25	331	89	61.1	67.9	29.5	29.4	40.6	39.9	71%	64%	16%	15%
1.25-1.50	84	21	45.1	49.2	25.0	20.3	39.3	30.8	66%	78%	20%	9%
1.50-2.00	101	32	62.7	73.4	30.9	36.0	48.1	54.6	71%	74%	14%	13%
2.00-3.00	417	133	65.2	63.3	30.7	29.6	38.8	38.3	75%	75%	12%	12%
>3.00	499	179	56.3	52.7	30.3	29.5	44.6	45.0	74%	65%	20%	23%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%	17%	16%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

Y: 5% < sample average

Such analysis of jobs-housing balance and travel behaviour is ground-breaking in the UK. Beyond the New Towns little research has been carried out, certainly not in recent years and at a county-wide level. As we can see, the majority of respondents live in household locations where the number of jobs is more than the number of households. Jobs-household balance ratios of less than one represent mainly residential areas; ratios of more than one represent areas with jobs outnumbering households. Note that jobs/household balance is measured at the ward level.

51% of respondents in 1998 (and 59% in 2001) live in locations where jobs/workforce balance is more than 2. Only 25% of respondents in 1998 (and 21% in 2001) live in locations which might be referred to as 'balanced' communities (the cohort 0.75-1.5 jobs/workforce) at the ward level. Interestingly the trend over time from 1998-2001 is to a reduced balance at the ward level.

The results show interesting non-linear trends - particularly bearing in mind we are considering simple bi-variate relationships:

- As might be expected, the more balanced jobs-housing ratios are associated with reduced energy consumption in the commute to work: for example, in 1998, households in the cohort 1.25-1.5 jobs-housing were 25% less energy consuming than the sample average (and 17% less in 2001).

[31] NB. Jobs and household balance: workplace jobs = (households x people per household ward average) x 0.66 average workforce for Surrey

- Journey to work distance and mode share contribute to these trends: balanced communities are associated with shorter commute distances, shorter journey times, less car dependency and increased public transport mode shares.

Correlation analysis however doesn't confirm the relationship very well. No association is proved. However, this is more a reflection of the weakness of the technique involved – only linear relationships are picked up by correlation analysis – and not evidence of lower energy consumption patterns at particular job-housing balance cohorts (e.g. the dip in energy consumption at the 1.25-1.5 ratio).

Table 4.14B: *Net Jobs and Household Balance and Travel Behaviour*

Land Use Variable	Correlation	EC98	EC01	JD98	JD01
jhb	Pearson Correlation	0.011	-0.005	0.008	0.045
	Sig. (2-tailed)	0.635	0.898	0.733	0.303

***Correlation is significant at the 0.01 level (2-tailed)*

**Correlation is significant at the 0.05 level (2-tailed)*

The following figures summarise this data in terms of jobs-housing balance and energy consumption.

Figure 4.28: *Net Jobs and Household Balance and Energy Consumption 1998*

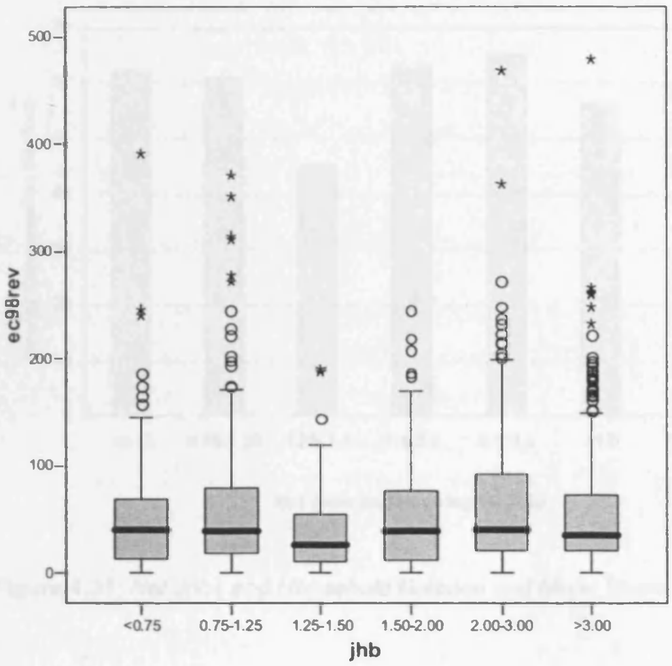


Figure 4.29: *Net Jobs and Household Balance and Energy Consumption 2001*

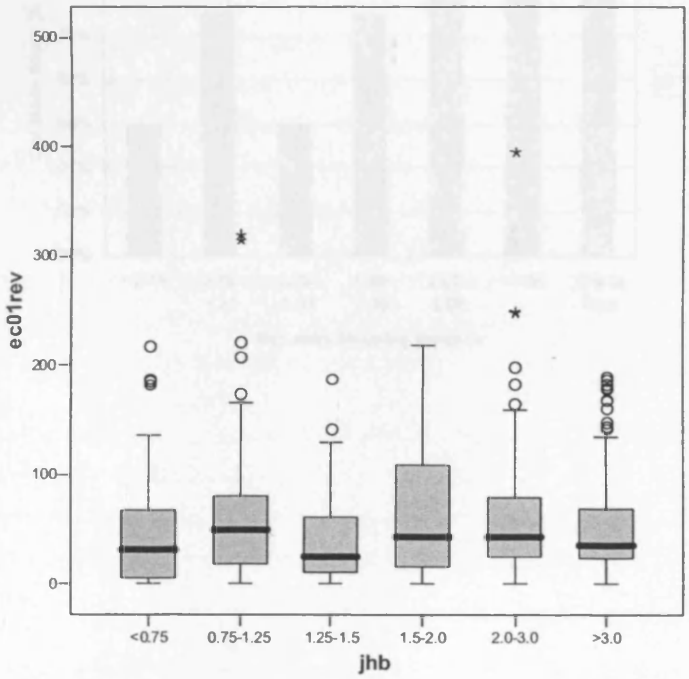


Figure 4.30: *Net Jobs and Household Balance and Energy Consumption*

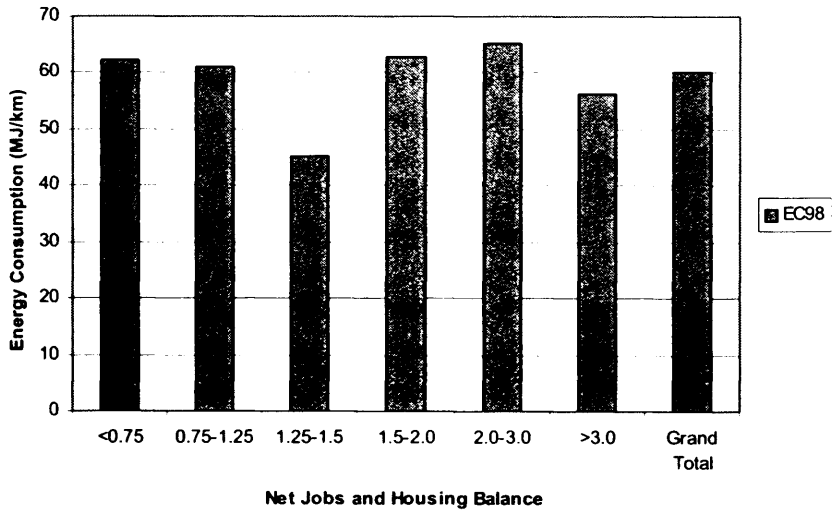
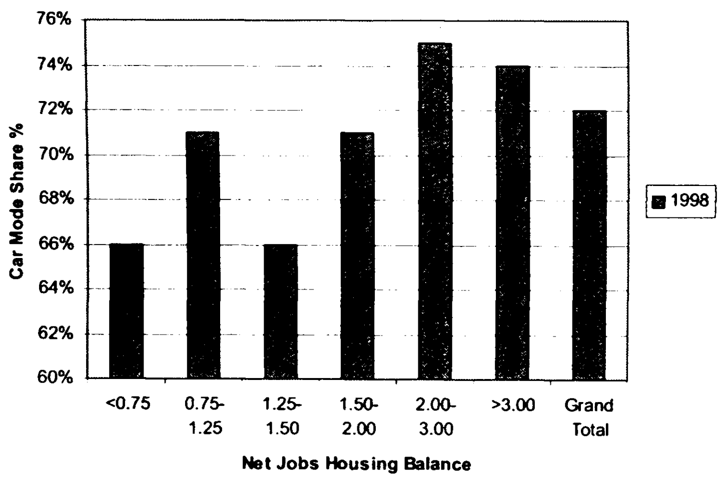


Figure 4.31: *Net Jobs and Household Balance and Mode Share*

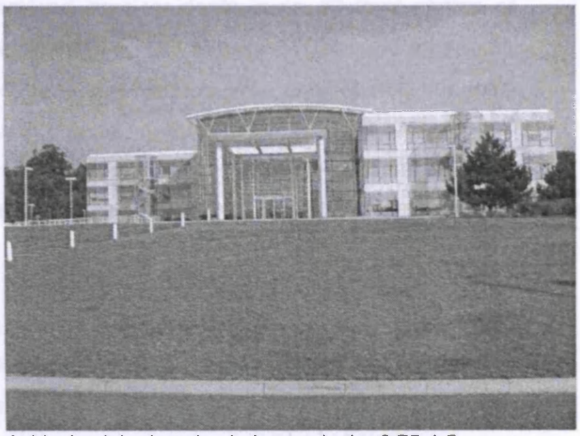


Dynamic Effects

In terms of dynamic jobs-housing balance in Surrey (using 2001 Census data); 341,918 residents live and work in Surrey; whilst 190,901 live in Surrey but work outside the county; and 145,184 live outside Surrey but work in the county. Hence a net out commute of 45,717. Data for Surrey is currently only available for 2001 and to the district level, hence the above net analysis cannot be repeated for dynamic effects at the ward level. This could usefully be the subject of further work.

Jobs and Housing Balance: Summary Thoughts

The debate on jobs-housing balance has been carried out mostly in the US; there is little comparable work in the UK in recent years (with the exception of some analysis in the New Towns). This appears to be a real research gap: the topic has a contribution to make in the land use and transport interaction field, despite plenty of criticism of the concept and its potential for use as a traffic management tool (see, for example; Gordon and Richardson, 1989a; and others).


Achieving jobs-housing balance - in the 0.75-1.5 jobs/household range - helps to reduce energy consumption in travel behaviour in Surrey. Jobs-rich or homes-rich zoning is associated with longer commuting trips (Brooklands Office Park, Woking).

The title of the article by Ewing (1995a) - "*Before we write off jobs-housing balance*" - is perhaps most appropriate to our conclusions. The concept is under-studied, particularly in the UK, but still appears to have great relevance to the Surrey experience.

At the ward level in Surrey, more balanced jobs-housing ratios are associated with reduced energy consumption in the commute to work: for example, in 1998, households in the cohort 1.25-1.5 jobs-housing were 25% less energy consuming than the sample average (and 17% less in 2001).

As we have seen, the analysis of jobs/housing balance can be carried out at a number of scales. Additional research may wish to consider other scales: town/borough/district or rural/urban distinctions or travel to work catchments. Future strategic urban planning in Surrey should certainly take into account the concept of jobs-housing balance - and plan for balanced urban form in the future.

There remain, however, a number of difficulties. Despite the intuitive attraction in having more people closer to their jobs in seeking to reduce vehicle miles travelled, reality on the ground - as usual - is more complicated. A number of issues have been picked up in the literature: workers in two earner households usually work in different locations; frequent job turnover reduces the ability to locate with reference to workplace; residential mobility is affected by housing price/income mismatches; and wider factors such as quality of the environment, schools, and location near to family and friends are important in choosing housing location. Jobs-housing balance also will have little effect on non-work trips: the largest growing travel segment. Many of these topics relating to choice of housing location are revisited later in this thesis (in Chapter 5).

Jobs-housing balance is also about much more than a simple quantitative match/mismatch. A qualitative fit of income and household choice, commute distance and other quality of life trade-offs is likely to be important. Gordon and Richardson etc. maintain that this is a natural evolutionary process brought on by market conditions and that over time co-location occurs. The Surrey data again shows that life is more complex than this: the housing-jobs market does not perform perfectly (a critique of all classical economic paradigms).

Much more detailed analysis is required to understand how residents trade off their choice of resident location with workplace location; of how this manifests itself at the individual and aggregate levels; and how imperfect market conditions (in Surrey, income/house price mismatches are likely to be very important) impact on travel behaviour. Cervero (1996a), for example, states that commuting is more sensitive to housing price than to housing supply. As stated previously, some of this discussion is returned to later in Chapter 5; however other parts could usefully be the subject of further research.

Finally, an important side issue: when comparing research on jobs-housing balance (and indeed any other urban form variables) between the UK and US, it should be noted that there is a difference in stage of urban development. Research on functional urban regions (see for example Cheshire, 2001) helps to enlighten us: essentially the UK is lagging behind the urban development trends of the US. In the UK there has not yet been the huge employment move to the suburbs. In very few areas do we find a disproportionate number of jobs outweighing housing, as for example is found in parts of California (typically the research area of Cervero and Gordon and Richardson). Indeed UK planning policy may stop this happening. Within suburban Surrey, the Blackwater Valley is perhaps the closest to the US experience, but housing still outnumbers employment. The position of Surrey is possibly one of 'absolute centralisation with some relative decentralisation'. Although the core remains dominant, the situation is changing. The outward shift of population and activity to the suburbs and remainder of the county is much increasing – certainly the majority of new households within the Surrey New Household Occupiers Survey are not found within the traditional central locations. Although research based on a case study area in the US, say California, is based on a different stage of urban development, the relative differences may be reducing. Further research on the jobs-housing balance concept should also seek to incorporate thinking on functional urban regions and stage of urban development.

4.2 Wider Land Use Influences

Following the consideration of the land use variables that are typically well researched in the literature, this section considers the land use variables which have been given less attention.

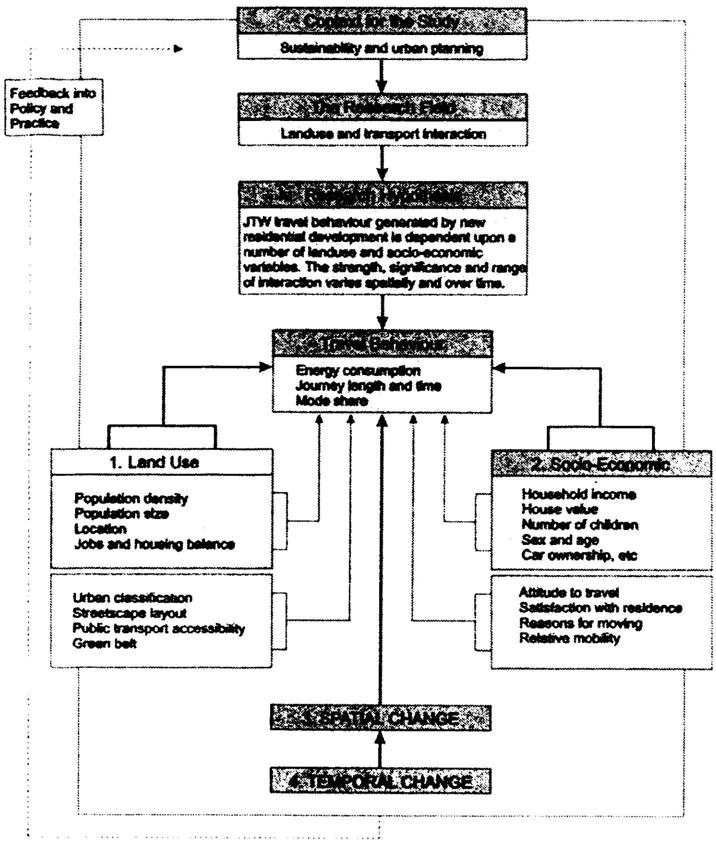
Research Question 2: The less well researched land use variables - what is the scale, strength, significance and range of influence of land use characteristics – such as strategic urban classification, local streetscape design, public transport accessibility and green belt designation – on travel behaviour.

H_0 – Travel behaviour is not related to these wider land use characteristics.

H_1 – Travel behaviour is related to these wider land use characteristics.

The key diagram below shows the relation of this part of the research to the rest of the empirical analysis.

Figure 4.32: *Wider Land Use Influences*



4.2.1 Strategic Urban Classification

Closely related to the discussion on population density, size and jobs-housing balance, but with a slightly different emphasis - and particularly under researched in the UK - is the urban concentration/polycentric concentration debate. Within this research, the discussion has centred on different travel behaviour associated with different urban forms, particularly commuting to the central city (monocentric form) or multiple centres (polycentric form). The evolving debate is again international in scope, and concentrates on relationships with travel behaviour in terms of journey distance, time and modal split; and less frequently energy consumption.

Schwanen et al (2001 and 2002a) provide a good overview of the literature and provide evidence from the Netherlands. They describe how, over the past few decades, the deconcentration of population and employment from the core of cities and towns to the periphery has led to many urban areas becoming multi-centered or polycentric. Instead of a strong concentration of jobs in the city centre, urban regions now have several employment and shopping centres. As a result, patterns of daily travel have become tangential or orbital, instead of radial in many regions. Schwanen et al highlight how, in the late 1980s, 57% of all the inter-municipal trips taken by the inhabitants of the Randstad in Holland were between suburban communities. Travel between the central cities and suburbs was less frequent at just 41% of trips (Cortie et al, 1992). Similar evidence is available for Paris (Bolotte, 1991; Jansen, 1993), Helsinki (Jansen, 1993), German cities (Schmitz, 1993), Swedish cities (Naess, 1995) and the US (Gordon and Richardson, 1996). There is little direct comparable analysis in the UK, possibly because of the lack of comparable data.

Reflecting the discussion in the density literature, some authors suggest that deconcentrated structures tend to reduce commuting distance and time. Gordon et al (1989a and 1991), using travel times, suggest that due to the higher congestion effects in high density monocentric cities, travel times are higher there than in low-density suburban communities in polycentric cities. 'Co-location' is believed to occur in the suburbs, where firms and households periodically re-adjust/locate spatially to achieve balanced average commuting distances and duration. The key reason for this job and residential mobility is individuals attempting to avoid the time penalties caused by congestion in urban areas. And, there may be other reasons, such high land prices, limited opportunities for spatial extension and poor accessibility from residences typically in suburban locations to employment focused in urban areas (Gordon and Richardson, 1991). In aggregate, the result is a dispersal of activities across urban space and the rise of polycentric urban areas with lower average commute times.

A number of studies broadly support the co-location thesis (see, for example, Levinson and Kumar, 1994). Schmitz also (1993) endorses the view that polycentric form is related to lower energy consumption patterns than monocentric form. Examining commuting regions in Germany, he found that commuters who cross the municipal borders in monocentric regions travel further on average than those who live in polycentric regions. Of course, such research findings are strongly dependent on spatial scale. In the UK, Jenks et al (1997) and Williams et al (2000) reflect the polycentricity viewpoint, suggesting that 'de-concentrated concentration' may be the optimum urban form in terms of reducing travel and energy consumption. Naess (1993a) concludes that for

Swedish commuting regions, and encompassing all towns and larger villages situated within 35km from the regional centre, when controlling for a number of socio-economic variables, a polycentric settlement structure makes the least demands on energy for transport. This applies for all travel purposes, however, each individual town and village must have a sufficiently high population density (see also, Naess et al, 1996). People living in remote sub-regional centres appear to take advantage of local jobs, services and leisure opportunities, and accept fewer options concerning service facilities and specialist jobs than in cities. However, at the lower spatial scale (in this case Greater Oslo) the degree of decentralisation has the opposite effect on energy use.

Other empirical studies have drawn different conclusions. As we have seen earlier, researchers such as Newman and Kenworthy (1989a) and Ewing (1997a) dispute the co-location hypothesis. Several other studies also add different nuances to the argument. In the San-Francisco Bay Area, Cervero and Wu (1998) find that, although the mean commuting distance of workers in suburban employment centres is shorter than for people working in downtown San Francisco, this difference has been narrowing during the 1980s. And, in terms of commuting, they suggest that times have increased far more rapidly in suburban employment centres than in downtown San Francisco. Both commute times and distances appear to rise with increases in the degree of polycentricism. Several phenomena may account for the longer commute in polycentric regions. Constraints on residential choice (and presumably employment choice) may prevent a minimisation of commute times and distance. There may be several workers in a household (Giulano and Small, 1993) or a lag in housing development near suburban employment concentrations (Cervero and Wu, 1997), or zoning measures creating green belts around urban nodes (Jun and Bae, 2000). Interestingly, Cervero and Wu also consider different population categories, suggesting that although overall commuting times and distances may be fairly stable or fall over time, the process of job decentralisation may increase the variation between individual workers. Giuliano and Small (1993) point out that a polycentric pattern of employment centres has the potential for shorter commuting times. Yet in Los Angeles, they concede that commuters in suburban centres actually travel only a few minutes less than downtown workers. Mokhtarian and Salomon (1997) point out that employment or residential relocation may serve as the means for households to escape congestion, but also function as a last resort when other strategies have proved inadequate. The reason behind this reluctance is that substantial costs are involved in changing jobs and particularly the place of residence, not only for the workers themselves, but also for other household members. The assumption of travel minimisation may also be challenged; at times, even for commuting trips, the journey itself may have intrinsic value and may be perceived as a positive rather than negative expenditure of time (Mokhtarian and Salomon, 2001).

Considerations on modal split are also interesting. Cervero and Landis (1995) and Cervero and Wu (1998) analyse the effect of deconcentration for the San Francisco Bay Area. They show how shifts in commuting behaviour, from using public transport to solo driving, are the main effect of job decentralisation. Similar effects were shown in Oslo (Naess 1996) and Melbourne (Bell, 1991). For the Paris region findings were different. Bolotte (1991) finds a growth in motorised suburban travel for the years 1971-1989, comprising 63% of the total. However, there was little change in modal split. His explanation lay in the investment in public transport infrastructure in Paris, keeping the market share stable at around 31%.

So, again, where does this leave us in terms of understanding? There is clearly some dispute as to the effects of urban form on travel behaviour. In the UK, the literature directly looking at the co-location debate, or monocentricity versus polycentricity, is sparse, with Spence and Frost (1995) and Curtis and Headicar (1994) coming closest with research on the distance from urban centres, and then, of course, Banister (1997a) and Williams et al (2000) and others etc. on questions of density and size. There is thus a direct need for further research here and greater clarity in findings.

The key issues for this thesis, in terms of the monocentric/polycentric debate, are:

- What impact does resident location have on the travel behaviour patterns of new households? Are houses located in suburban or rural areas associated with higher energy consuming travel patterns, longer journey to work lengths and times, and higher car dependency than those in town centres?

- What impact does the type of journey to work destination have on the travel behaviour patterns of new households? Are tangential journeys to work associated with higher energy consuming travel patterns, longer journey to work lengths and times, and higher car dependency than radial journeys to work?

EVIDENCE FROM SURREY: STRATEGIC URBAN CLASSIFICATION

The evidence is considered in two different ways, first by disaggregating the Surrey dataset into different types of resident location: town centre, rest of urban area and rural - see Figure 4.33. And second, by attempting to unravel the complexity in commuting patterns in a particular way - by considering the type of journey to work – which are typically either radial (suburban to major centre) or tangential (suburb to suburb).

Figure 4.34 shows the complexity in journey to work movements (in 1998) for new housing occupiers in just one new development to the north Horley. As might be expected a number of local trips are evident - with commutes to Horley itself, Gatwick and Horsham. Further afield we can identify some typical 'traditional' radial trips - to London and Croydon for example. What night be surprising is the extent of tangential commutes - using the M25 - to workplaces at quite a distance such as Leatherhead, Dorking and Hayes (Middlesex). It is these types of commutes that are growing in number - and that are poorly served by the current public transport offer. Hence they are very likely to be car based.

Obviously a map of the complete dataset would be extremely detailed (and difficult to read). Hence the next sections attempt to disaggregate the commute origins and destinations to further understand the trends on the ground. Chapter 6 (particularly Figure 6.2) also further explores the changes that are experienced over time.

Figure 4.33: *Resident Location – Urban Classification*

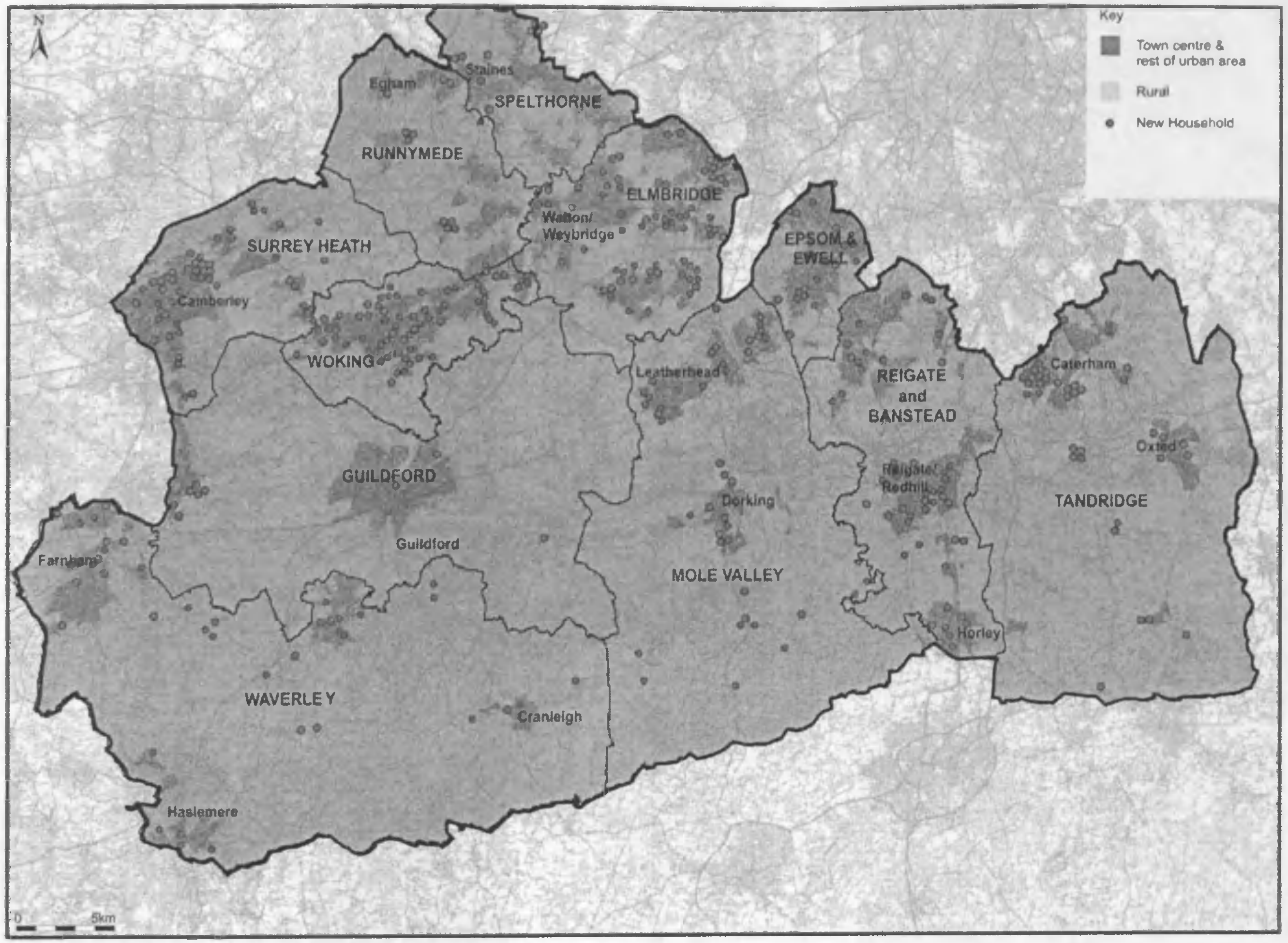
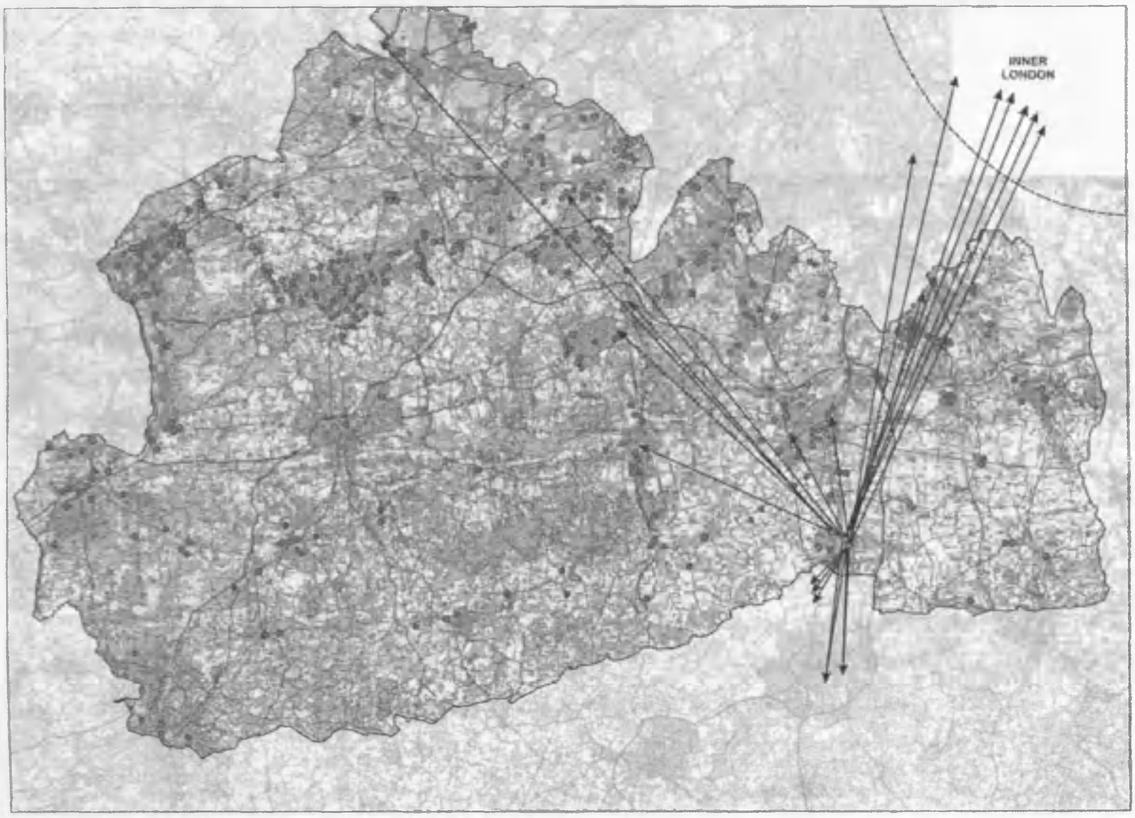


Figure 4.34: *Types of Journey to Work*



Resident Location – Urban Classification

Below we show resident location categories – town centre, rest of urban area and rural – and their associated travel behaviour. Urban area is defined using the boudaries as found in the respective Local Plan.

Table 4.15A: *Resident Location and Travel Behaviour*

Resident Location	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver		% Train	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Town Centre	246	72	54.4	66.9	31.2	33.0	46.7	47.2	62%	59%	22%	22%
Rest of Urban Area	1,132	348	59.6	56.0	29.3	27.8	40.5	39.8	74%	69%	16%	16%
Rural	275	105	67.2	65.7	32.3	30.2	43.8	42.4	74%	69%	15%	13%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%	17%	16%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

Y: 5% < sample average

The vast majority of respondents live in the 'rest of the urban area' category (68% of the sample in 1998, falling to 66% in 2001). Town centre residents account for 15% in 1998 and 14% in 2001; and rural residents 17% in 1998, increasing to 20% in 2001

A number of trends are evident:

- As might be expected, average energy consumption in 1998 is higher for rural areas than town centres (24% higher) or the rest of the urban area (13% higher). This is due to longer commute trips and a high mode share by car. 2001 data provides less clear results.

- Travel behaviour patterns are somewhat more complicated than the policy thrust of PPG13 might imply, i.e. there is not a simple association of shorter commutes and reduced car dependency in urban areas, with the reverse in rural areas. Low % car mode shares are found in town centre locations, however, because there is a high public transport mode share (and in particular train) and because in Surrey these trips are often long distance – upto 60km into London - journey to work distance and time is lengthy. Energy consumption is not too high because of high rail occupancy in the AM peak. Rest of the urban area locations perform better in energy consumption terms in 1998; shorter trip distances and trip times compensating for the higher % car mode share. As noted previously, rural locations remain the highest energy consumers; with long trip distances (but not time) and high % car mode shares.

Chi-square analysis confirms these findings – there is a significant relationship between resident location and energy consumption (in the 1998 data).

Table 4.15B: *Resident Location and Travel Behaviour*

Chi-Square Test	Value	df	Asymp. Sig. (2-sided)
Resident Location (Urban Area)-EC98			
Pearson Chi-Square	13.57	4	0.009**
Resident Location (Urban Area)-EC01			
Pearson Chi-Square	15.06	10	0.130

*****Chi-square is significant at the 0.01 level***

****Chi-square is significant at the 0.05 level***

The following figures summarise this data in terms of resident location and energy consumption.

Figure 4.35: *Resident Location and Energy Consumption 1998*

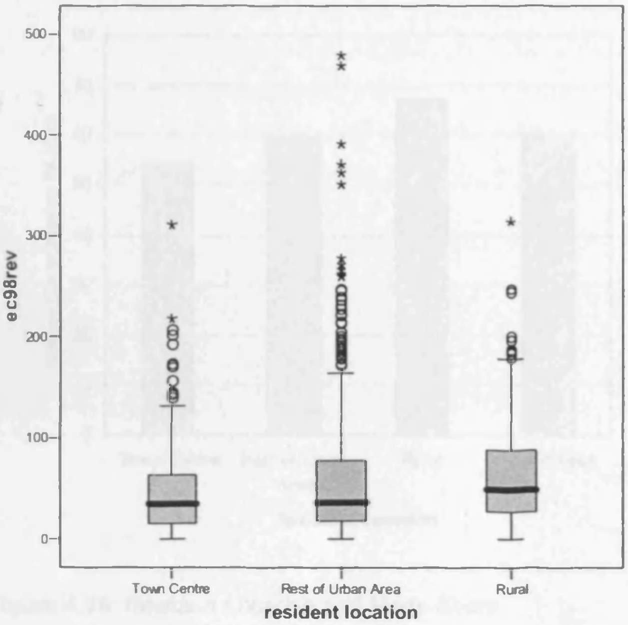


Figure 4.36: *Resident Location and Energy Consumption 2001*

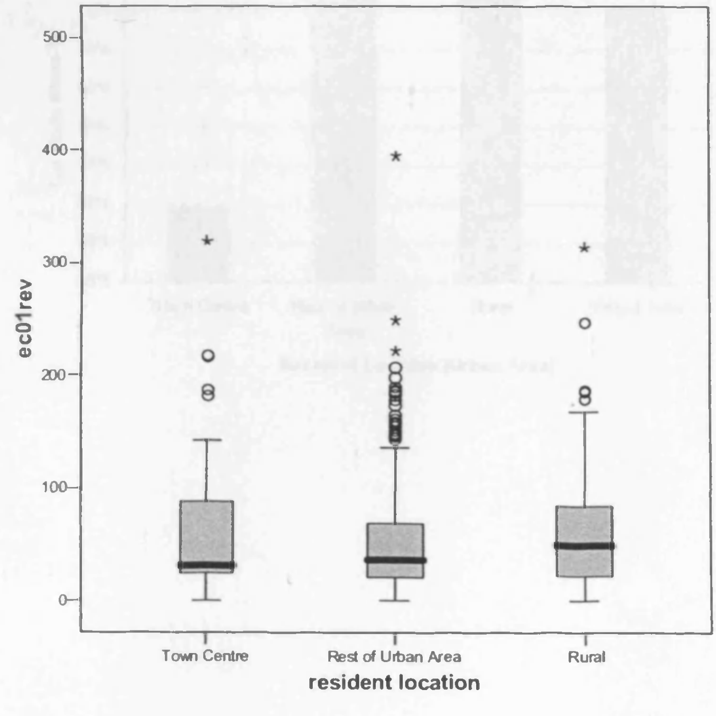


Figure 4.37: *Resident Location and Energy Consumption*

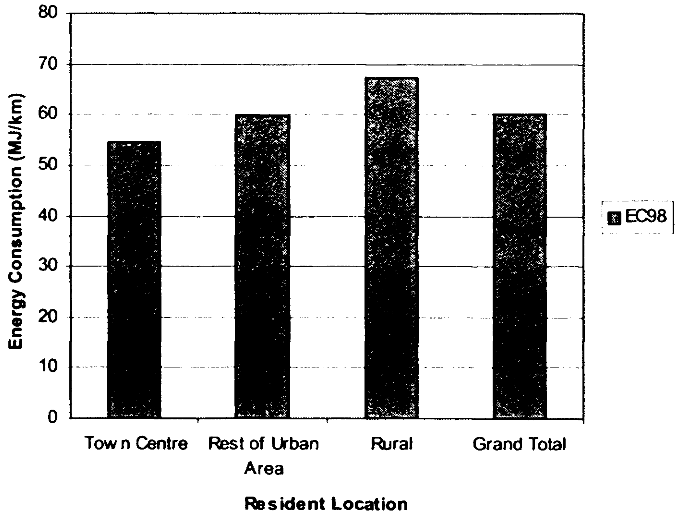
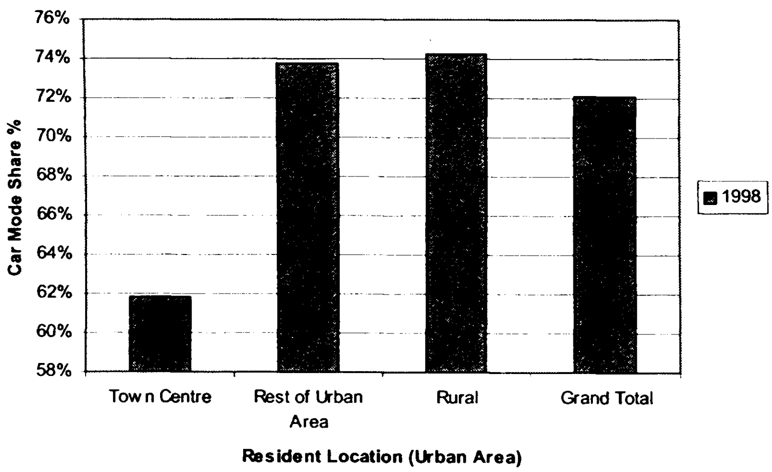


Figure 4.38: *Resident Location and Mode Share*



Type of Journey to Work Destination

Below these issues are considered in slightly greater depth - type of journey to work in terms of resident origin and workplace destination, and just using 1998 data (for sample size reasons). There are a number of interesting findings. For almost all workplace destinations the most energy consuming trips are made from rural resident origins; and these high energy consumption patterns are mainly due to high journey lengths rather than mode share differences.

Table 4.16: *Type of Journey to Work and Travel Behaviour*

Workplace (Destination)		Resident Location (Origin)			
		Town Centre	Rest of Urban Area	Rural	Grand Total
		1998	1998	1998	1998
Inner London	Count	67	211	47	325
	EC (MJ/jtw) (Index relative to sample average 100)	44.7	50.8	58.0	50.6
	JD (km)	58.4	56.6	64.0	58.1
	% Car	13%	22%	21%	20%
Outer London	Count	42	284	58	384
	EC (MJ/jtw) (Index relative to sample average 100)	65.2	71.9	92.0	74.2
	JD (km)	24.6	27.3	34.0	28.0
	% Car	88%	85%	88%	86%
7 Key Towns	Count	43	170	24	237
	EC (MJ/jtw) (Index relative to sample average 100)	45.0	28.7	69.4	34.9
	JD (km)	10.5	10.1	24.5	11.6
	% Car	72%	82%	74%	74%
Other 33 Towns	Count	51	211	58	320
	EC (MJ/jtw) (Index)	40.7	41.9	48.4	42.9
	JD (km)	11.6	14.6	16.4	14.5
	% Car	75%	88%	83%	85%
Other Rural	Count	7**	73	27	107
	EC (MJ/jtw) (Index)	58.0	38.7	37.7	39.8
	JD (km)	20.2**	13.2	11.6	13.2
	% Car	100%**	85%	89%	87%
Other Adjacent Counties	Count	34	169	58	261
	EC (MJ/jtw) (Index)	90.3	84.0	77.1	83.4
	JD (km)	41.3	37.6	32.9	37.0
	% Car	91%	93%	93%	93%
Surrey Total Sample	Count	246	1,132	275	1,653
	EC (MJ/jtw)	54.4	59.6	67.2	60.1
	JD (km)	31.2	29.3	32.3	30.1
	% Car	62%	74%	74%	72%

Data: Surrey New Occupiers Survey 1998.

(NB. EC – energy consumption; JD – journey distance. Sample size: *<20, **<10 respondents)

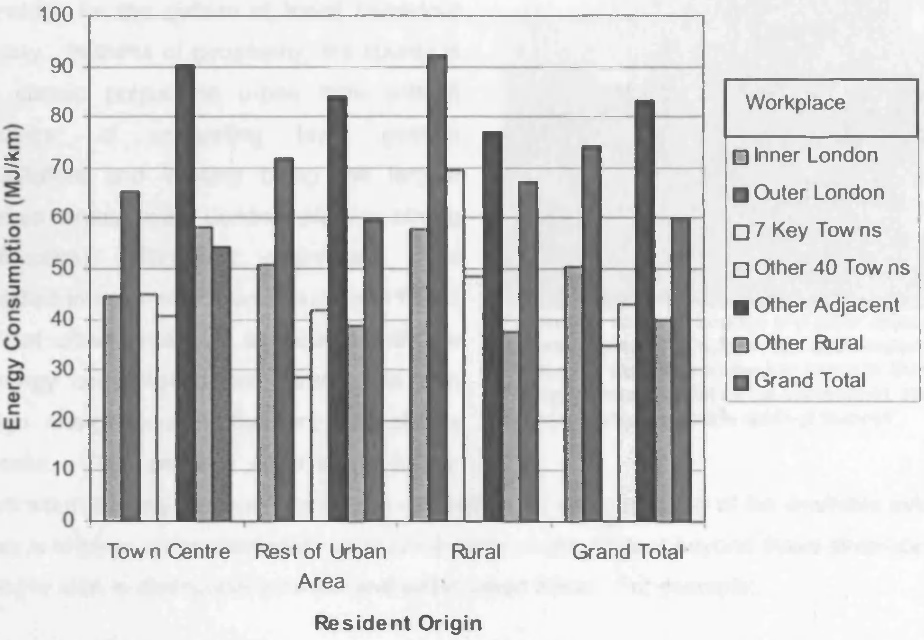
Shading Key

X: 5% > sample average

Y: 5% < sample average

Each resident origin and workplace destination has its own particular travel behaviour patterns and these are described in Figure 4.39 and in the following commentary:

Figure 4.39: *Type of Journey to Work and Travel Behaviour*



- Inner London – all journey to work trips are high in energy consumption due to the trip lengths involved (an average of 58km in 1998). Of the town centre residents working in Inner London only 13% use the car in 1998. Those from rural resident location origins are the highest energy consumers due to the higher journey distances (an average of 64km in 1998; 100% more than the sample average distance).

- Outer London – journey to work trips are high in energy consumption due to the lengthy distances involved and high car dependency.

- It is to the 7 key town and other 33 town workplace destinations where journey to work energy consumption is lowest in the new household sample. For example, journey to work trips to the 7 key towns are 42% less energy consuming than the sample average in 1998. From town centre or rest of urban area residences to the 7 key town workplaces energy consumption is even less: in 1998 approximately 64% less than the sample average.

- Journey to work trips to other adjacent counties are the highest energy consuming of all trip types, accounting for 39% more in energy consumption than the sample average in 1998; a function of long journey to work distances and high car dependency. Interestingly, for work trips to other adjacent counties, households located in urban areas are associated with the highest energy consumption patterns and the longest journey distances.

Strategic urban classification and type of journey to work: summary thoughts

Commutes to Outer London and other adjacent counties are associated with high energy consumption patterns. Journey to work trips to the key towns in Surrey are less energy consuming (A4 Great West Road, Hounslow: a popular workplace to the north of Surrey)

Hence we have a complex picture of commuting - one that takes some unpicking. The Jane Jacobs billiard table is a useful analogy for the pattern of travel behaviour today. In terms of geography, the county is a classic polycentric urban form with a number of competing town centres (Guildford and Woking being the largest urban areas; with London also a strong attraction). Simplistic distinctions - as implied in national guidance such as PPG13 - that urban areas are associated with low energy consumption and rural areas with high energy consumption are not always useful. They certainly need to be further refined at the regional and local levels - based on an understanding of the available evidence. The key is to try to understand what commuting patterns are evident beyond these simplistic definitions and to start to distinguish between and within urban areas. For example:

- Trips from households in rural areas are high energy consumers (12% higher than the sample average in 1998).

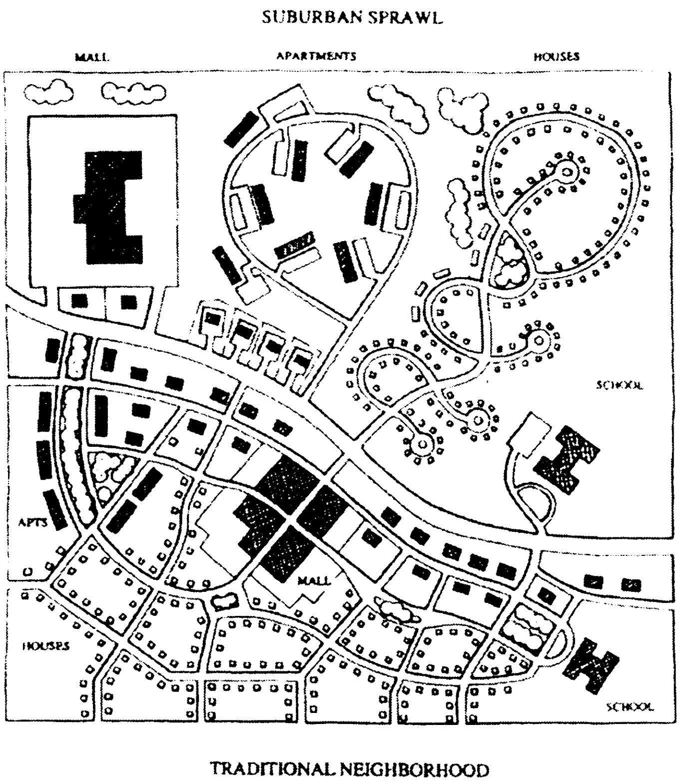
- Certain types of commute are associated with disproportionately high energy consumption patterns, e.g. commutes to Outer London and to other adjacent counties or to distant parts of Surrey facilitated by trips along the M25. The implication for policy - if reduced energy consumption is a key objective - may be to encourage greater self-sufficiency of individual towns with enhanced local public transport networks serving the immediate hinterlands. For Surrey this may include less reliance on Outer London as a workplace destination.

Travel behaviour in Surrey is thus strongly influenced by London, and the pattern of commuting appears to getting more and more complex. Strategic planning such as that found in the South East Plan or Surrey Structure Plan needs to be based on a thorough understanding of commuting behaviour on the ground. Journey to work trips to the 7 key towns in Surrey, for example, remain the least energy intensive of all destinations. Over time, radial commuting is becoming more infrequent and a greater number of tangential trips are occuring - including for example trips to other adjacent counties, reverse commutes and suburb to suburb trips. This change is leading to increased journey lengths and greater car mode share. Commuting patterns are thus changing dramatically, yet we have very little understanding of changed behaviour, and even less understanding of the reasons for change. Unfortunately the current public transport network is not designed to serve these types of commuting patterns.

4.2.2 Local Neighbourhood Streetscape Layout

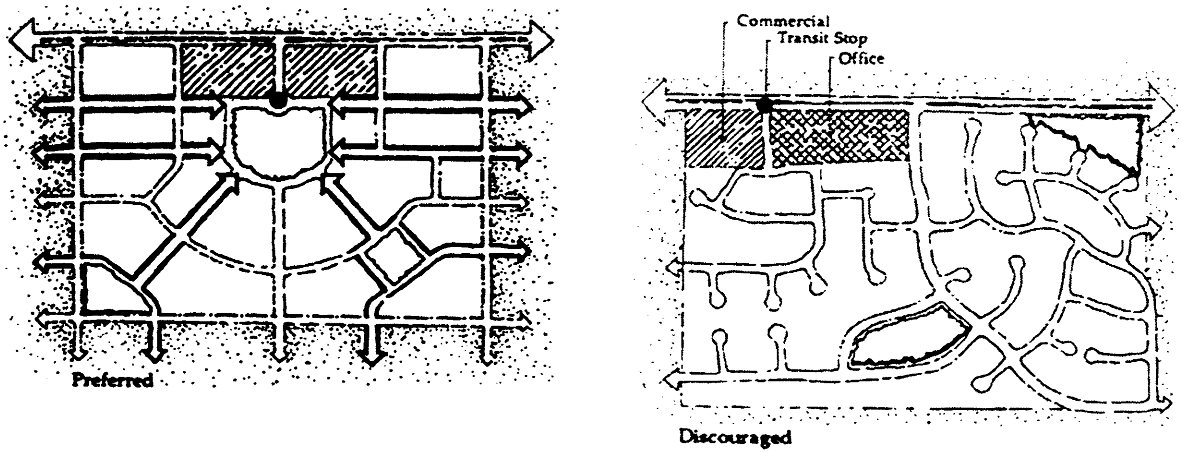
The land use/transport relationship is likely to manifest itself at different scales. At the local level, a number of studies, mostly in the US, have looked at the impact of local neighbourhood streetscape layout on travel behaviour. Crane (1999) gives a good overview of the literature, the general thesis being that traditional grid-style development patterns are associated with greater use of walking, cycling and public transport, and less use of the private car, than suburban sprawl and cul-de-sac type developments. A number of the studies in the USA have grown out of the New Urbanism movement; and a few of the well-known examples are shown in Figures 4.40-4.42.

Figure 4.40: *A Comparison of 'Suburban Sprawl' and 'Traditional' Neighbourhood Development.*



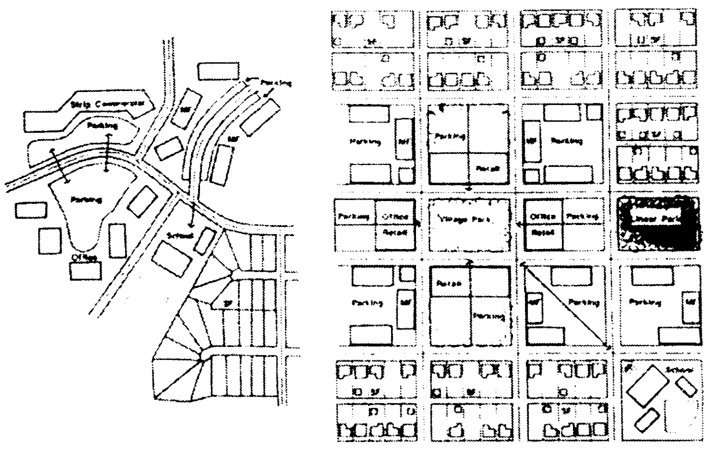
(Duany and Plater-Zyberk, 1992)

Figure 4.41: *'Preferred' and 'Discouraged' Street and Circulation Patterns in the 'Transit-Oriented' Development Guidelines*



(Calthorpe Associates, San Diego 1992)

Figure 4.42: *'Conventional' Suburban Development and 'Traditional' Neighbourhood Development*



A. Conventional Suburban Development (CSD)

B. Traditional Neighborhood Development (TND)

(Kulash, Anglin and Marks, 1990)

It is ironic that the debate over moving away from suburban low-density sprawl and single land use areas, and at remodelling existing urban areas around public transport and walkable communities, is strongest in North America. The US in particular has spent the last half-century removing reference to public transport as a factor in urban development. However, North America is supplying much of the new jargon that is used here, for example: 'Transit Oriented Development', 'Smart Growth', 'Transit Districts', 'Pedestrian Pockets' (see, for example, Morris and Kaufman, 1998; Duany and Plater-Zyberk, 1991; and Calthorpe, 1993).

Marshall (2003), amongst others, has usefully critiqued the 10-year history of the New Urbanism movement, describing the movement as "an urban design package combining neo-traditional style buildings with street grids, forming relatively dense, walkable mixed-use communities". He comments on the many criticisms in the literature: from being not sufficiently new, nor urban enough, being part of the suburban problem, too pastiche, formulaic and physically deterministic. Southworth (2003) similarly considers what New Urbanism has achieved and whether it can be considered ecologically sensitive, concluding that city-wide impacts have been few and far between. The new urbanists therefore are possibly teaching us little more than what has been accepted urban design practice in the UK for the last decade and more. Talk of new urbanism has however begun to reach the mainstream planning press in the UK.

In terms of urban design and travel behaviour impacts, the concept of Transport Development Areas (RICS, 2000) leans heavily on the US-developed transit-orientated development. Thought is mainly centred on concentrating development around public transport nodes, and providing communities designed for walking and cycling.

Few researchers actually consider how travel behaviour might be influenced by design. Kulash et al (1990) suggest that "traditional" circulation patterns reduce vehicular motorised traffic by 57% compared to more conventional networks (which appears to be a remarkably high figure). The results are however criticised as the authors assumed trip frequencies were fixed in their study.

The Portland LUTRAQ simulations (1000 Friends, 1996) are also interesting. They forecast that higher population densities near transit corridors with subsidised transit will increase the share of transit work trips. The forecasts are however reliant on inputs and assumptions to the modelling (the expected diversion effects).

Cervero and Gorham (1995) examined matched pairs of communities selected to compare "transit-oriented" land use patterns with more typical post-World War II developments. They compared work and non-work trip generation rates for seven pairs of neighbourhoods in the San Francisco Bay area and six pairs of neighbourhoods in the greater Los Angeles metropolitan area. They hypothesised that transit oriented neighbourhoods generate more pedestrian and transit trips. These neighbourhoods were identified using street maps, and transit service information. The authors suggest that street layouts do influence commuting behaviour - transit neighbourhoods averaged higher walking and cycle modal shares and generation rates than did their automobile counterparts. However, this finding held only for the Bay Area neighbourhoods. In the Los Angeles-Orange County comparisons, the differences in the proportion of transit or pedestrian trips between the transit and automobile oriented neighbourhoods were negligible.

Rutherford, Scott, McCormack and Wilkinson (1996, p.54) also summarise actual travel behaviour, using more detailed individual level travel diary data. They conclude that their information "*generally supports the notion that mixed-use or neo-traditional neighbourhoods can reduce the amount of travel for most households ... although we concur with others that the linkage is very complex. Residents of the two mixed-use neighbourhoods in Seattle travelled 27% fewer miles than the remainder of North Seattle, 72% fewer than the inner suburbs and 119% fewer than the outer suburbs.*" The study does acknowledge that these neighbourhoods differ in several respects, such as age, labour force participation, and income, but the nature of the analysis does not permit a formal examination of the roles of those differences.

Again, the evidence is consistent with the idea that people in mixed-use neighbourhoods travel differently, but it neither demonstrates that the mixed-use character of the neighbourhood is responsible nor does it establish that reducing the land use conformity (i.e. little mix in uses) of suburban neighbourhoods would change residents' travel behaviour.The key issues for this thesis, in terms of the local neighbourhood layout debate, are:

- What impact does neighbourhood layout have on the travel behaviour patterns of new households?

- Are houses located in suburban sprawl (cul-de-sac) type developments associated with higher energy consuming travel patterns, longer journey to work lengths and times, and higher car dependency than those in more traditional (grid street network) style developments?

EVIDENCE FROM SURREY: LOCAL NEIGHBOURHOOD STREETSCAPE LAYOUT AND TRAVEL BEHAVIOUR

Household locations are divided into three categories using a desk-top analysis of local neighbourhood street layout[32]. The categories used are as below:

- Neo-traditional grid street pattern

- Cul-de-sac near to a village/town centre[33]

- Cul-de-sac remote from a village/town centre[34]

Shading Key

X: 5% > sample average

Y: 5% < sample average

Table 4.17A: *Local Neighbourhood Streetscape Layout and Travel Behaviour*

Local Neighbourhood Urban Layout	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver		% Train	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Neo-traditional grid	1,205	386	57.3	59.5	29.1	28.3	41.5	40.3	71%	67%	17%	17%
Cul-de-sac near to village/town centre	296	96	67.2	54.0	32.5	28.9	43.4	42.8	74%	69%	17%	17%
Cul-de-sac remote from village/town centre	152	43	68.2	70.8	33.5	36.0	42.8	47.9	80%	71%	14%	14%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%	17%	16%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

[32] using The Surrey Street Atlas, Phillips (2003).
[33] Cul-de-sac definition = three or more routes off one access. Near to village/town centre (a Post Office or rail station within 10 minutes/800m walk)
[34] Cul-de-sac definition = three or more routes off one access. Remote from village/town centre (a Post Office or rail station beyond 10 minutes/800m walk)

There is a relatively clear relationship between local neighbourhood streetscape layout and energy consumption (certainly in the 1998 data).

The vast majority of respondents live in locations with 'neo-traditional grid' street patterns (73% of the sample in 1998 and 74% in 2001). Locations with 'cul-de-sac' form near to a village/town centre account for 18% of the sample in both 1998 and 2001; and locations with 'cul-de-sac' form remote from village/town centres account for 9% in 1998 and 8% in 2001.

Cul-de-sac developments often make walking and cycling trips lengthy, and discourage public transport usage. Such developments are associated with higher car dependency and higher energy consumption travel behaviour patterns than traditional grid style networks (Godstone, Tandridge)

A number of trends are evident:

- As might be expected, average energy consumption is lower in neo-traditional grid locations (5% lower than the sample average in 1998). This is due to shorter commute trips and a low mode share by car.
- Households in cul-de-sacs near to a village/town centre are 12% higher in energy consumption than the sample average in 1998.
- Households in cul-de-sacs remote from a village/town centre are the highest energy consumers: 12% higher in energy consumption than the sample average in 1998.

Chi-square analysis confirms these findings – there is a significant relationship between neighbourhood streetscape layout and energy consumption (in the 1998 data). The 2001 dataset provides less clear results here (and for the analysis concerning some other variables in the thesis) – potentially a reflection of a reduced number of respondents or attrition issues. The main analysis therefore focuses on 1998 data.

Table 4.17B: *Local Neighbourhood Streetscape Layout and Travel Behaviour*

Chi-Square Test	Value	df	Asymp. Sig. (2-sided)
Neighbourhood Design-EC98			
Pearson Chi-Square	29.30 [g]	10	0.001**
Neighbourhood Design-EC01			
Pearson Chi-Square	4.68 [h]	4	0.322

***Chi-square is significant at the 0.01 level*

**Chi-square is significant at the 0.05 level*

The following figures summarise this data in terms of distribution and neighbourhood streetscape layout cohort. The results here look very positive: build new houses with traditional grid street patterns and average energy consumption is likely to be reduced. However, the rationale behind travel behaviour is, of course, not that simple (there are other factors at work).

The premise of this thesis is to highlight the wide range of factors behind an individual's travel choices. All these are inter-related; and in combination result in a unique travel behaviour pattern for an individual. At the aggregate level these translate into major movement flows. Action on one front - say designing new households with traditional street patterns - will probably affect travel behaviour only slightly, if at all. For example, attitudes to household location and travel (see Chapter 5) may override this initial neighbourhood layout change. In Surrey, residents might aspire to low density living with cul-de-sac designs, gardens and garages. Action on a wide number of fronts - including the attitudinal angle - might however start to modify aggregate travel behaviour patterns in a "sustainable" direction.

Gated communities: a variation on the residential design theme; such developments have a long history in Surrey and certainly do not encourage movement through the areas in question (gated and security-guarded entrance to St George's Hill, Weybridge)

Yet more 'Fortress Surrey': the proliferation of new gated residential developments throughout Surrey is staggering (Weybridge), replicating a phenomenon experienced across the world, from California and Cairo, to São Paulo and Bogota. Surely the 'mean streets of Surrey' don't necessitate this? The objectives of permeability and inclusiveness are certainly not achieved here.

Figure 4.43: *Local Neighbourhood Streetscape Layout and Energy Consumption 1998*

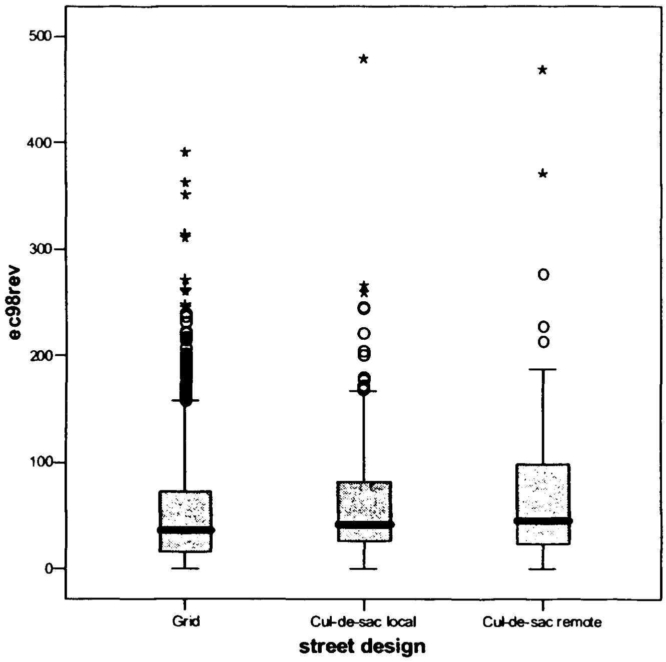


Figure 4.44: *Local Neighbourhood Streetscape Layout and Energy Consumption 2001*

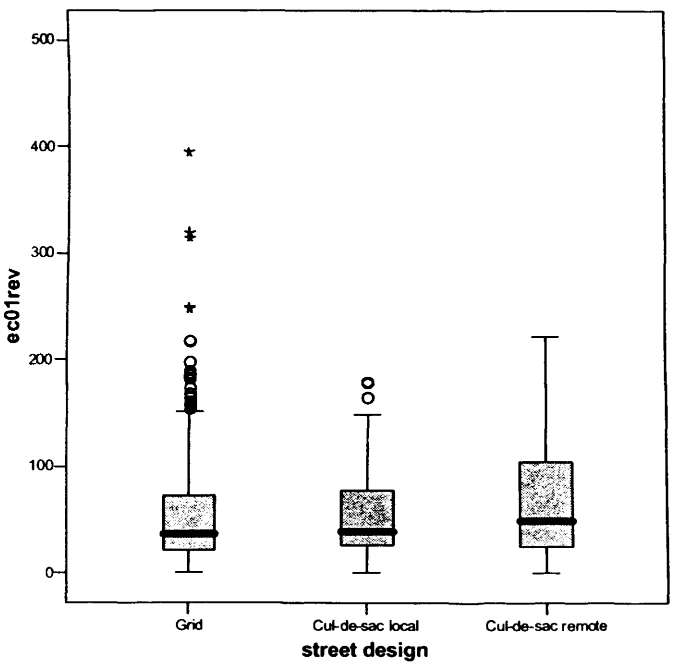


Figure 4.45: *Local Streetscape Layout and Energy Consumption*

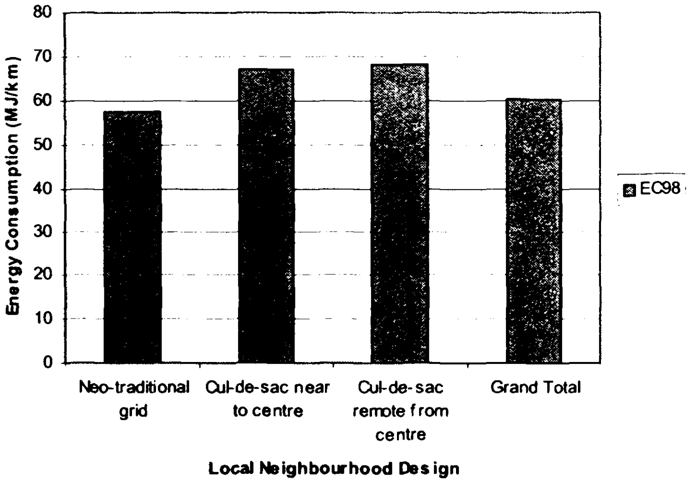
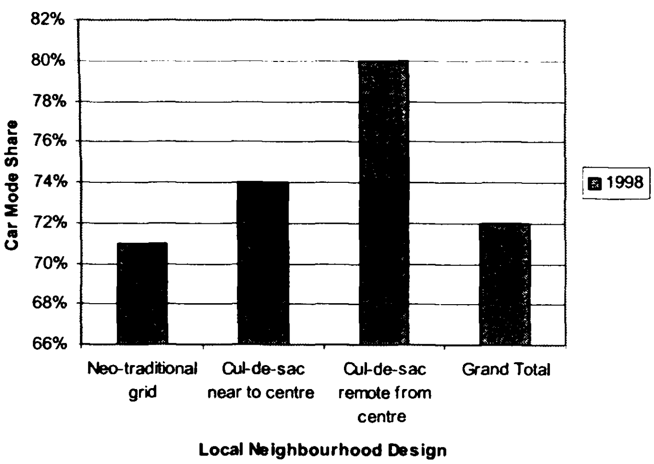


Figure 4.46: *Local Streetscape Layout and Car Mode Share*



North of Godstone: new residential development, cul-de-sac style, remote from the local village centre, and located for quick access to the M25.

Map scale: 500m^2 grid

South of Dorking: classic cul-de-sac sprawl to the south of the town. A walk trip from these types of developments can take 10 minutes before the surrounding road network (let alone a destination) is reached.

St George's Hill: gated, exclusive housing, built at low densities, from 1914 onwards by W.G. Tarrant, around a golf course, other leisure facilities and open land. Home to the seriously rich (Cliff Richard is one famous resident). Ironically, St George's Hill was originally occupied by the Diggers, an agrarian collective in the 17th Century (and a group akin to land reformers the Levellers). Other similar exclusive estates abound in Surrey, for example the Wentworth Estate; all are very car dependent.

		
Frimley: cul-de-sac development, again associated with lengthy commuting trips, dependent on the car.	West End: yet further car dependent, cul-de-sac development.	Whiteley Village: again exclusive housing in Surrey, but this time, a self contained retirement community with Grade II listed cottages, residential homes and a nursing home, built around an octagonally shaped street network, and set in 240 acres of woodland.

4.2.3 Public Transport Accessibility

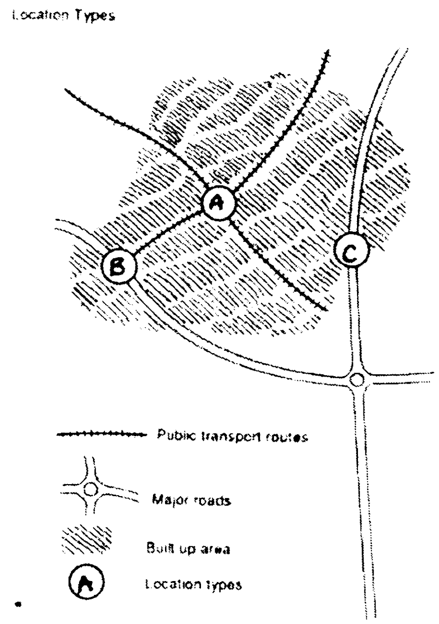
Strongly related to the access to urban areas discussion (and the flip side to access to the strategic highway network) is the influence of public transport accessibility on travel behaviour.

The Netherlands provides much of the leading-edge research here, particularly in considering the public transport accessibility and development location trade-off. Since 1988, the Dutch Government has been developing a transport and land use policy, called '*the right business in the right place: towards a location policy for business and services in the interests of accessibility and the environment*', and commonly known as the ABC location policy.

The working of the ABC location policy has frequently been studied in the UK: Amundson (1993), Pharoah (1992) and McInerny (1996) give a good initial overview. The policy aims to match the mobility needs of businesses and other land use activities with the accessibility characteristics of particular locations. The policy was specifically designed for urban areas and the location of major trip-generating activities. Offices, shops, services, leisure, recreation, entertainment, cultural, education and health facilities are all covered, but not residential land use or rail freight. Locations are given 'accessibility profiles' and businesses and other activities are given 'mobility profiles', each classified A, B or C. The aim is to match the accessibility and mobility profiles (A-A, B-B, C-C), as outlined in Figure 4.47.

There have been recent concerns in the Netherlands that there is a shortage of A and B locations, and this has led some to try and discredit the policy approach. Critically, large amounts of investment in public transport are required to generate more and more A locations.

Figure 4.47: *ABC Location Policy in the Netherlands*



(From Pharoah, 1992)

Accessibility profiles have become ever more strictly defined in terms of the standard of public transport service expected. Examples are defined below:

- A locations: served mainly by public transport, centred on a railway station in a town or city centre, served by fast and frequent inter-city services to other towns and cities. Stringent car parking policies are applied with the aim that no more than 10-20% of commuters travel by car. In the Randstad companies are only allowed 10 parking spaces per 100 employees; outside the maximum is 20 spaces per 100 employees.

- B locations: reasonably well served by both public and private transport. Public transport should take the form of a suburban rail station (with at least 30-minute service frequency), Metro station, light rail stop or hub of the local bus service (at least two routes crossing).

- C locations: without a good public transport service, but easily accessible by car (at least 2km from a motorway of dual carriageway).

Mobility profiles are defined for each proposed new development according to trip generation characteristics. These are based on: number of employees per floor area, number of visitors per floor area, dependency by employees on the use of the car for work, and reliance on road freight. A labour intensity of one employee per 40 m^2 is considered to be high; one per $100m^2$ to be low. Profiles are not inclusive, with considerable overlap between. Example activities are shown below:

- A mobility profile: industry, offices, government departments, administration centres, social services, shops, hotels, restaurants, universities, schools, major social and cultural facilities, medical and veterinary services, etc.

- B mobility profile: offices with a high dependence on the car for work activities, hire businesses, industry with high employment intensity, wholesale business and transport undertakings, clothing industry, graphics industry, communications companies, sport and recreational activities, etc.

- C mobility profile: petroleum industry, wood and furniture industry, chemical industry, base metals, paper, textiles, metal products, leather, electrotechnical, machine, food and luxury items, building materials, wholesale trade, warehousing and distribution.

There has similarly been a growing interest in accessibility planning in the UK. Amongst the 'market leaders' were the London Borough of Hammersmith and Fulham who developed public transport access profiling (known as PTALS) for the borough. Access from and to the public transport network is measured, by distance and time, using GIS or manual systems. Accessibility mapping has been taken up by more and more local authorities in recent years, including Surrey County Council, and is beginning to be used in relation to development proposals.

In the US further thought has been given to public transport accessibility and impact on travel behaviour. Kitamura et al (1997) report that the distance from home to the nearest bus stop and railway station affects modal share. The proportion of car journeys increases and the proportion of non-motorised journeys decreases with increasing distance from the nearest bus stop. Cervero (1994) shows how the proportion of rail journeys decreases with increasing distance from the nearest railway station. Residents living within 150 metres of a railway station in California typically use rail for approximately 30% of all journeys. The further the distance from the railway station, the lower the proportion of rail journeys made. Residents living at a distance of 900 metres from the nearest railway station are likely to make only about half the number of rail journeys. Cervero reports that this pattern of rail use is similar in Washington, Toronto, Edmonton and California.

The key issues for this thesis, in terms of the public transport accessibility debate, are:

- What impact does public transport accessibility have on the travel behaviour patterns of new households?
- Are houses located in areas of poor public transport accessibility associated with higher energy consuming travel patterns, longer journey to work lengths and times, and higher car dependency than those located in areas of good public transport accessibility?

EVIDENCE FROM SURREY: PUBLIC TRANSPORT ACCESSIBILITY

The development of accessibility modelling in Surrey (the county provides much of the leading-edge research in this area in the UK, at least prior to the development of Accession modelling across the UK) allows us the match public transport isochrones with new household locations and travel behaviour. Household locations are categorised according to accessibility isochrones, using journey times by public transport (through the network) to the nearest town centre (28 town centres are used)[35]. Figure 4.48 shows the accessibility surface in Surrey, together with the locations of the new household occupiers.

[35] Surrey County Council kindly provided the accessibility mapping here, using their PTAM software.

Figure 4.48: *Public Transport Accessibility*

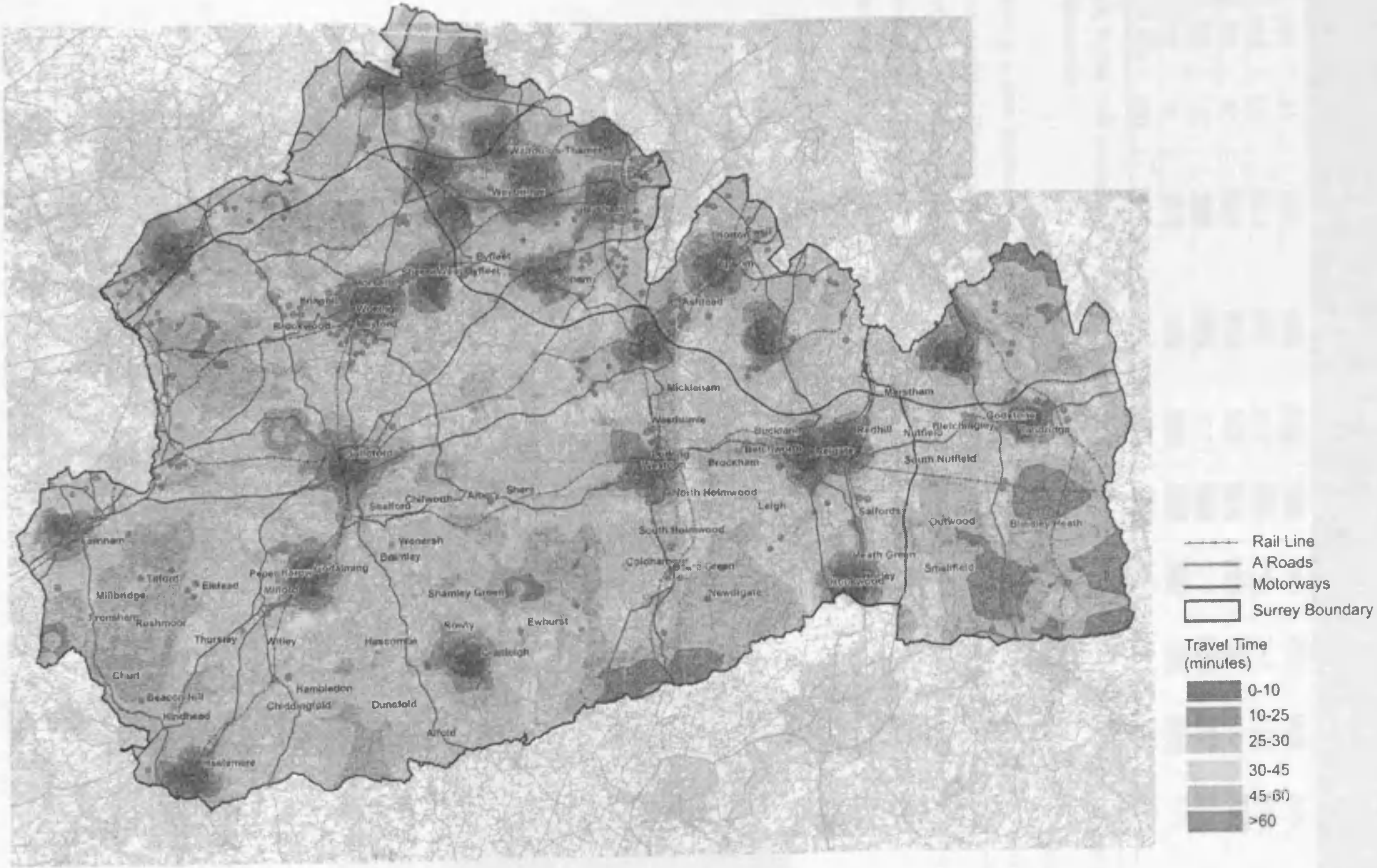


Table 4.18A: *Public Transport Accessibility and Travel Behaviour*

Public Transport Accessibility Band (Time from Town Centre)	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver		% Train	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
0-10 minutes	326	91	53.7	54.2	28.2	25.1	42.0	37.1	65%	65%	19%	16%
10-25 minutes	446	124	58.2	54.0	29.5	27.1	41.3	39.5	71%	67%	17%	19%
25-30 minutes	202	67	52.1	49.5	26.2	23.5	37.7	33.2	73%	75%	16%	14%
30-45 minutes	393	132	63.5	62.5	30.7	32.2	42.3	46.7	77%	64%	16%	20%
>45 minutes	257	98	73.9	72.5	35.4	34.5	44.3	46.2	78%	72%	13%	11%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%	17%	16%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

Y: 5% < sample average

There is a clear relationship between public transport accessibility and energy consumption. Respondents are spread fairly evenly throughout the public transport accessibility isochrones (59% of the sample in 1998 and 54% in 2001 are within 30 minutes of a town centre). A number of trends are evident:

- As might be expected, average energy consumption is lower for households located close to the town centres; and higher for those located further away. The 25-30 minute isochrone is associated with the least energy consuming patterns (13% less than the sample average in 1998); households located closer to the urban area are likely to commute longer distances by rail.

- By far the highest energy consumers are households over 45 minutes from the urban areas (consuming 23% more than the sample average in 1998).

Energy consumption is lower for households located within a 30-minute public transport journey time of the main centres in Surrey. Those located in less accessible locations are associated with higher energy consumption patterns. Note the poor design quality of the rail station (Sunbury Railway Station, Spelthorne).

The following figures summarise this data in terms of distribution and accessibility cohort.

Figure 4.49: *Public Transport Accessibility and Energy Consumption 1998*

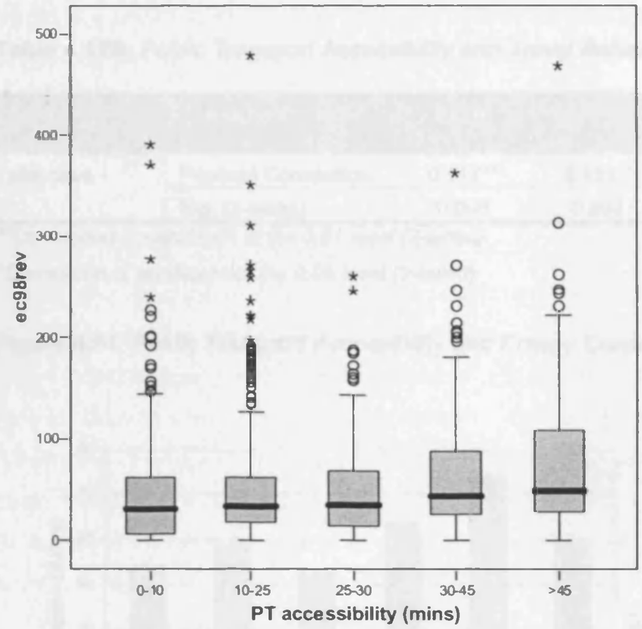
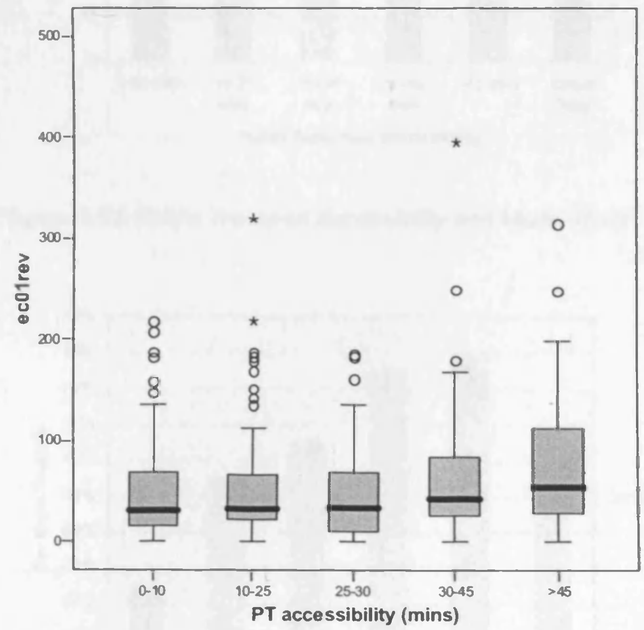


Figure 4.50: *Public Transport Accessibility and Energy Consumption 2001*



Correlation analysis confirms these findings – there is a significant relationship between public transport accessibility and energy consumption and journey distance.

Table 4.18B: *Public Transport Accessibility and Travel Behaviour*

Land Use Variable	Correlation	EC98	EC01	JD98	JD01
ptaccess	Pearson Correlation	0.117**	0.133**	0.073**	0.138**
	Sig. (2-tailed)	0.000	0.002	0.003	0.002

***Correlation is significant at the 0.01 level (2-tailed)*
**Correlation is significant at the 0.05 level (2-tailed)*

Figure 4.51: *Public Transport Accessibility and Energy Consumption*

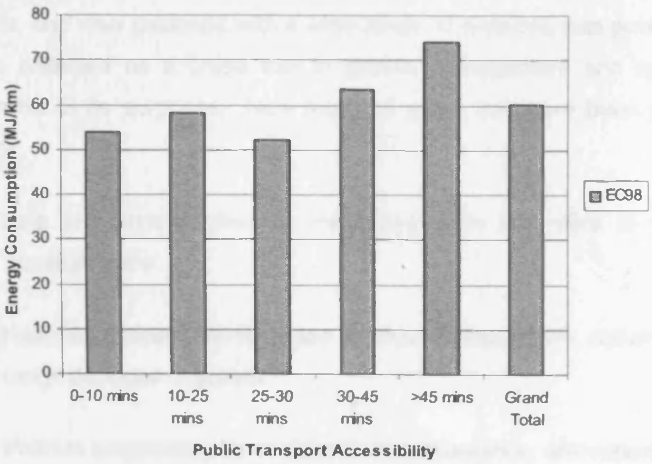
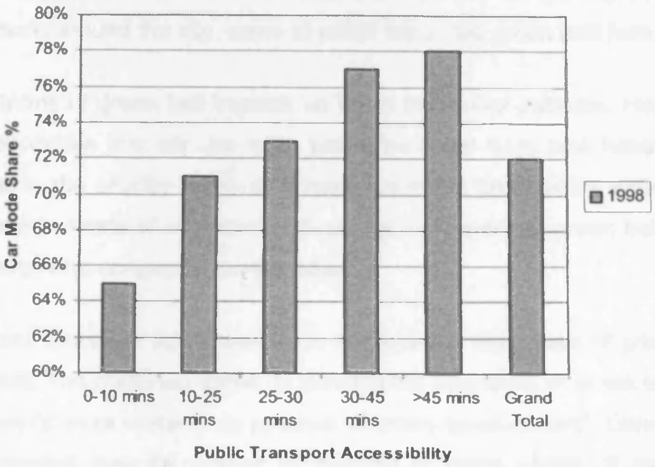


Figure 4.52: *Public Transport Accessibility and Mode Share*



4.2.4 Green Belt

There is a separate and distinct literature field on the use and value of green belt policy in the UK. We do not draw on all of this, except to consider the particular dimension of the impact of green belts on travel behaviour. The main argument being that green belt provision increases journey lengths as people are 'forced' to live beyond the green belt as the urban area becomes 'filled' to capacity.

Authors such as Elson (for example 1993, 1998 and 1999) and the Town and Country Planning Association have long argued that the current role of green belts should be re-examined. The RTPI (2002) have also recently examined the issues. Elson argues that as an icon of planning history, green belts appear immune from serious critical assessment, but that no planning policy should remain exempt from periodic reassessment. Green belt policy last had a revamp in the early 1990s, and new guidance with a wide range of revisions was published in 1995. Green belts have been criticised as a crude tool in growth management and one that is too extensive for the fulfilment of its purposes. New forms of green belt have been proposed in Wales, for example, where:

- Less emphasis is given to continuous belts and more to 'green wedges', 'green lungs' or 'strategic gaps'

- Restraint policies are regarded as channelling growth, rather than acting as a stopper or long range deflector of growth

- Policies emphasise the avoidance of coalescence, and retention of the settings of urban areas as important functions, rather than other purposes

A number of counties in the UK already use similar designations, for example Leicestershire, Hampshire, Wiltshire and West Sussex; and Cambridge City Council are actively looking at growth options around the city, some of which are in the green belt (see Llewelyn Davies, 2002).

In terms of green belt impacts on travel behaviour patterns, Headicar (1997) points to evidence in Oxfordshire that car use rates would be lower from new housing located in Oxford's green belt, than in the country towns as designated in the Oxfordshire structure plan. A trade-off needs to be made in terms of environmental quality, between the green belt on the one hand, and emissions, energy and congestion on the other.

It may therefore be necessary to address the objectives of green belts as set out in PPG2 (DoE, 1995). The guidance states, in defining the intentions of green belts, that they "can assist in moving towards more sustainable patterns of urban development". Given the evidence reported above, this statement may be difficult to support in some cases. It may be that urban extensions into designated green belt land may be more sustainable (at least in transport terms), than development beyond the green belt. Such developments could, for example be served by extensions to existing urban public transport radial services. Alternatively, more selective incursions of green belt may be possible for new or expanded settlements around stations on railways that pass through green belt land.

It should be noted that the five reasons given in PPG2 for including land in green belt, as listed below do not address the issue of transport sustainability. And so there may be other reasons for retaining green belt beyond their transport impact.

- To check the unrestricted sprawl of large built up areas
- To prevent neighbouring towns from merging into one another
- To assist in safeguarding the countryside from encroachment
- To preserve the setting and special character of historic towns
- To assist in urban regeneration, by encouraging the recycling of derelict and other urban land

The green belt issue is of course simply a more formal and specific aspect of the wider town versus country debate that goes back before green belt designation, to Ebenezer Howard and the Victorian philanthropists. Headicar (1997) believes that greater priority should be given to development in and around the largest urban areas, even if this means that the extent of the green belt has to be re-considered. Research needs to make more explicit the merits of the largest urban areas as locations combining choice with proximity, and hence in lessening both the amount and share of car-based travel. This applies particularly where the major settlement in a region has a disproportionate share of jobs and higher order facilities. Subject to whatever local opportunities are available for brown land development within the urban area, this will almost certainly involve a reconsideration of the green belt and other similar local growth management policies.

Therefore the key issues for this thesis, in terms of green belt impacts, are as listed below:

- What impact does green belt designation have on the travel behaviour patterns of new households?
- Are houses located in the green belt or countryside beyond the green belt associated with higher energy consuming travel patterns, longer journey to work lengths and times, higher car dependency than those in urban areas?

EVIDENCE FROM SURREY: GREEN BELT AND TRAVEL BEHAVIOUR

To help examine the above issues, the data was disaggregated into three resident location types; urban area, green belt and countryside beyond the green belt, as shown in Figure 4.53. Table 4.19A provides a cross-tabulation of travel behaviour by location type.

Figure 4.53: *Resident Location (Relative to the Green Belt)*

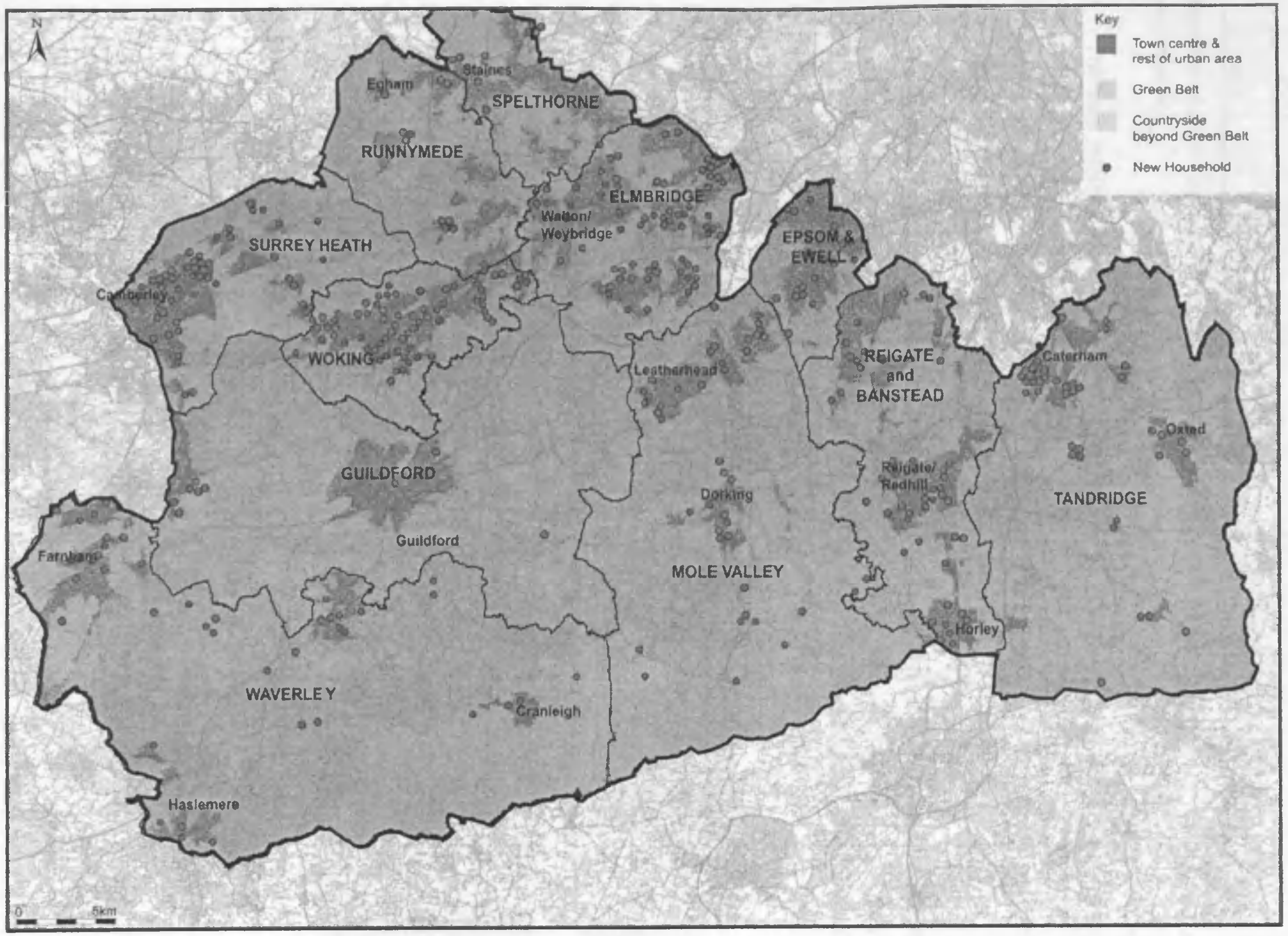


Table 4.19A: *Resident Location and Travel Behaviour*

Resident Location	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance (Km)		Average of Journey to Work Time (Mins)		% Car Driver		% Train	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Urban	1,376	416	58.7	57.0	29.8	28.5	41.9	41.2	72%	66%	17%	18%
Green Belt	223	87	64.0	66.2	30.1	27.9	41.8	39.5	74%	72%	14%	9%
Countryside Beyond the Green Belt	54	22	78.1	76.6	38.7	44.1	43.2	51.6	78%	75%	14%	21%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%	17%	16%

Data: Surrey New Occupiers Survey 1998 and 2001. . (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

Y: 5% < sample average

- The vast majority of new households are located in the 'urban area' (83% of respondents in 1998 and 79% in 2001[36]). Respondents in green belt locations account for 13% in 1998 and 17% in 2001, and countryside beyond the green belt locations for 3% in 1998 and 4% in 2001.

- Travel behaviour patterns are very interesting: energy consumption is lowest in the urban areas, rising markedly in green belt locations and particularly in locations in countryside beyond the green belt (the latter 30% higher in energy consumption than urban locations). This figure is due to higher journey lengths, times and higher car dependency.

The findings in Surrey appear to be clear: green belt policy is associated with increased energy consumption patterns, higher commuting journey distances and times and higher car dependency, particularly for households located beyond the green belt. Over time these households become ever more intensive in their energy consumption; travelling on average further in their journeys to work. Green belts may of course be useful for other purposes, however their side effect in terms of encouraging longer distance commutes provides a problem. Other forms of green belt may prove to be more effective in future years.

Green belt designation: useful for a series of objectives - such as preventing urban coalescence, etc. - but at times has a side effect in increasing journey distances and energy consumption.

The following figures summarise the data in terms of distribution and resident location cohort.

[36] The disaggregation used gives data by respondent rather than by household.

Figure 4.54: *Resident Location (Green Belt) and Energy Consumption 1998*

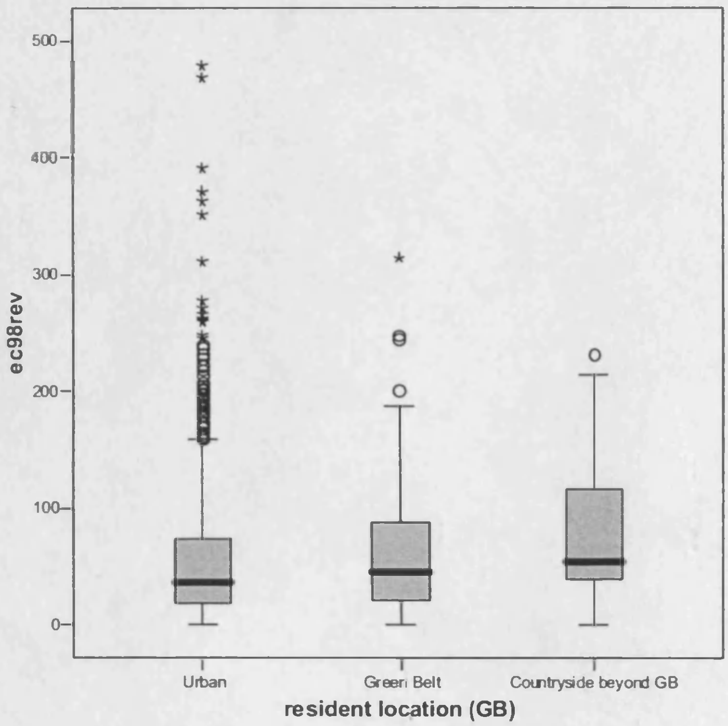
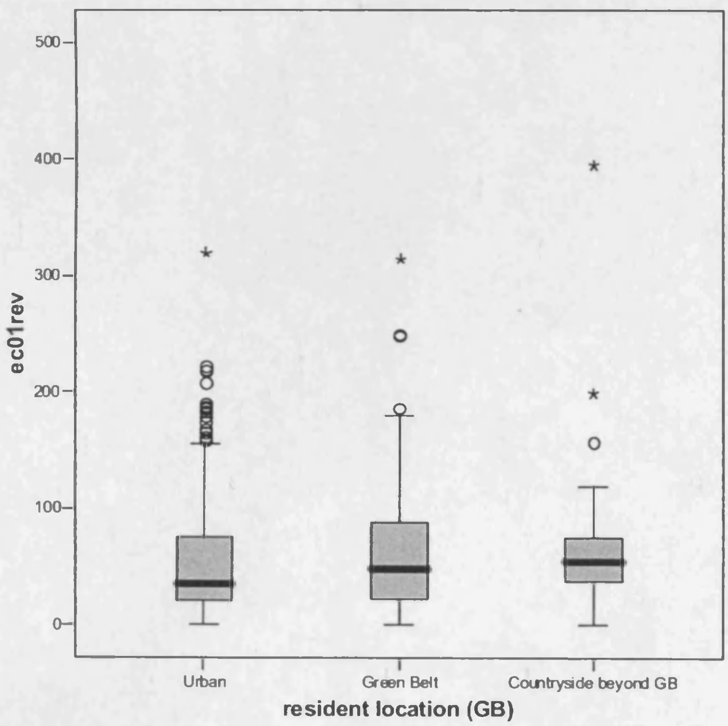


Figure 4.55: *Resident Location (Green Belt) and Energy Consumption 2001*



Chi-square analysis confirms these findings – there is a relationship between resident location and the green belt and energy consumption (at least in the 1998 data).

Table 4.19B: *Resident Location and Travel Behaviour*

Chi-Square Test	Value	df	Asymp. Sig. (2-sided)
Resident Location (Green Belt)-EC98			
Pearson Chi-Square	12.17	4	0.016*
Resident Location (Green Belt)-EC01			
Pearson Chi-Square	4.52	4	0.340

***Chi-square is significant at the 0.01 level*

**Chi-square is significant at the 0.05 level*

Figure 4.56: *Resident Location (Green Belt) and Energy Consumption*

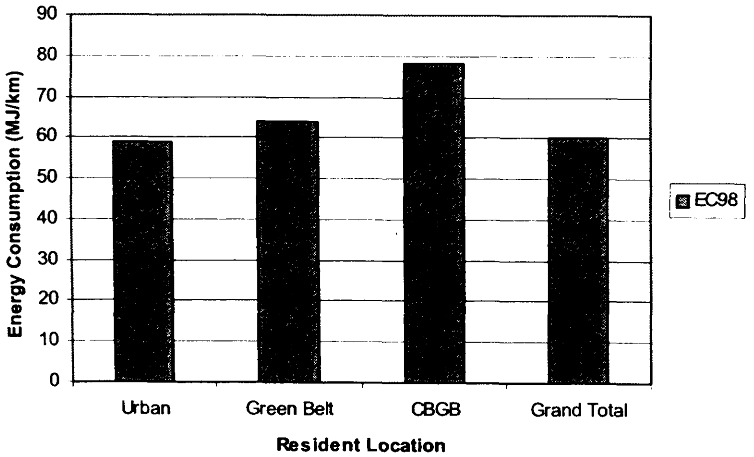
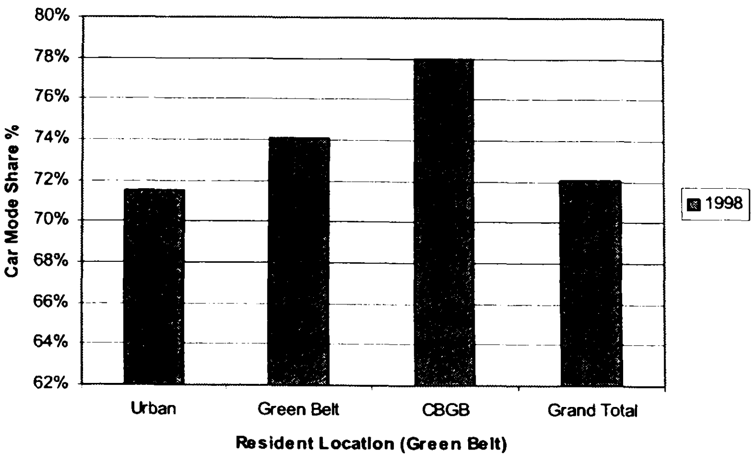


Figure 4.57: *Resident Location (Green Belt) and Car Mode Share*



4.3 Land Use Conclusions

The section below draws together the findings of this chapter on land use and travel behaviour. It focuses on the high and low energy consuming groups and also draws together previous bi-variate and chi-square analysis.

High and Low Energy Consumers

The high and low energy consumers are defined as those cohorts consuming at least 10% more or less than the sample average (see Figure 4.58)

Figure 4.58: *The High and Low Energy Consuming Cohorts*

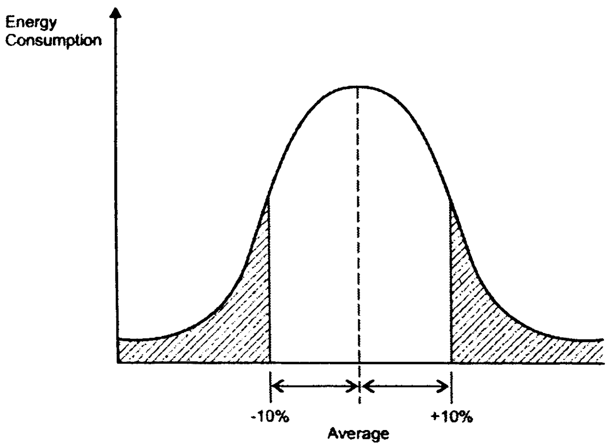


Table 4.20 and Figures 4.59-4.60 show the high and low energy consumers (the latter using 1998 data only). A number of groups consume over 15% more than the sample average, as outlined below:

- Residential population density: 0-1 persons/ha;
- Workplace population: Outer London or Other Adjacent County;
- Distance from London: >50km;
- Location adjacent to strategic road network: M3 and A31;
- Various resident-workplace trip types: such as rural residences-London workplaces;
- Public transport accessibility: >45 mins;
- Resident location: Countryside beyond the Green Belt.

Most of these high energy consuming patterns are associated with long distance commutes by car. The topic of long distance commuting is returned to later in the thesis (see Chapter 5, page 251).

Table 4.20: *The Land Use High and Low Energy Consumers*

High and Low Energy Consuming Cohorts *(At Least +/-10% Relative to Sample Average)*	**Count**		**Average of Energy Consumption (MJ/jtw)**		**Index: Energy Consumption Relative to Sample Average**	
	1998	2001	1998	2001	1998	2001
Resident Population Density						
0-1	51	20	69.4	67.2	+15%	+13%
>35	143	37	42.5	37.6	-29%	-37%
Res Emp Density						
0-1	268	110	68.7	61.4	+14%	+3%
10-20	338	90	46.2	44.3	-23%	-25%
20-35	88	26	65.9	41.9	+10%	-30%
Resident Pop size name						
7 key towns	339	100	66.9	58.9	+11%	-1%
Other Rural	562	200	62.5	65.6	+4%	+10%
Workplace Pop size name						
Inner London	325	115	50.6	65.1	-16%	+10%
Outer London	384	107	74.2	68.8	+23%	+16%
7 key towns	237	67	36.1	36.8	-40%	-38%
Other 40 Towns	320	93	42.9	43.1	-29%	-27%
Other Rural	107	36	39.8	47.5	-34%	-20%
Other Adjacent	261	97	83.4	70.0	+39%	+18%
Distance from London						
20-30km	226	72	42.4	40.1	-29%	-33%
30-40km	669	199	54.2	52.8	-10%	-11%
40-50km	426	154	64.2	67.4	+7%	+13%
50-60km	212	54	78.4	71.2	+30%	+20%
>60km	120	46	80.8	74.9	+34%	+26%
Df Road Network						
M3	173	39	78.4	67.8	+30%	+14%
A3	148	29	54.1	58.6	-10%	-1%
A31	136	48	78.1	74.3	+30%	+25%
None	731	259	54.3	58.5	-10%	-2%
JHB						
0.75-1.25	331	89	61.1	67.9	+2%	+14%
1.25-1.5	84	21	45.1	49.2	-25%	-17%
1.5-2.0	101	32	62.7	73.4	+4%	+24%
>3.0	499	179	56.3	52.7	-6%	-11%
Resident Location						
Town Centre	246	72	54.4	66.9	-9%	+13%
Rural	275	105	67.2	65.7	+12%	+11%
Grand Total	**1,653**	**525**	**60.1**	**59.4**	**0%**	**0%**

High and Low Energy Consuming Cohorts *(At Least +/-10% Relative to Sample Average)*	1998 NHOS		
	Count	EC	Index
Resident-Workplace Trip Type			
TC-IL	67	44.7	-26%
RoUA-IL	211	50.8	-15%
RoUA-OL	284	71.9	+20%
Rural-OL	58	92	+53%
TC-7 Key	43	45	-25%
RoUA-7 Key	170	28.7	-52%
Rural-7 Key	24	69.4	+15%
TC-Other 33	51	40.7	-32%
RoUA-Other 33	211	41.9	-30%
Rural-Other 33	58	48.4	-19%
RoUA-Other Rural	73	38.7	-36%
Rural-Other Rural	27	37.7	-37%
TC-Other Adjacent	34	90.3	+50%
RoUA-Other Adjacent	169	84	+40%
Rural-Other Adjacent	58	77.1	+28%
Rural-All Workplaces	275	67.2	+12%
Grand Total	**1,653**	**59.4**	**0%**

High and Low Energy Consuming Cohorts *(At Least +/-10% Relative to Sample Average)*	Count		Average of Energy Consumption (MJ/jtw)		Index: Energy Consumption Relative to Sample Average	
	1998	2001	1998	2001	1998	2001
Streetscape Design						
Cul-de-sac near to centre	296	96	67.2	54.0	+12%	-9%
Cul-de-sac remote from centre	152	43	68.2	70.8	+13%	+19%
Public Transport Accessibility						
0-10 mins	326	91	53.7	54.2	-11%	-9%
25-30 mins	202	67	52.1	49.5	-13%	-17%
>45 mins	257	98	73.9	72.5	+23%	+22%
Resident Location (Green Belt)						
Green Belt	223	87	64.0	66.2	+6%	+11%
CBGB	54	22	78.1	76.6	+30%	+29%
Grand Total	**1,653**	**525**	**60.1**	**59.4**	**0%**	**0%**

Figure 4.60: *The Land Use High and Low Energy Consumers (At Least +/-10% >Sample Average)*

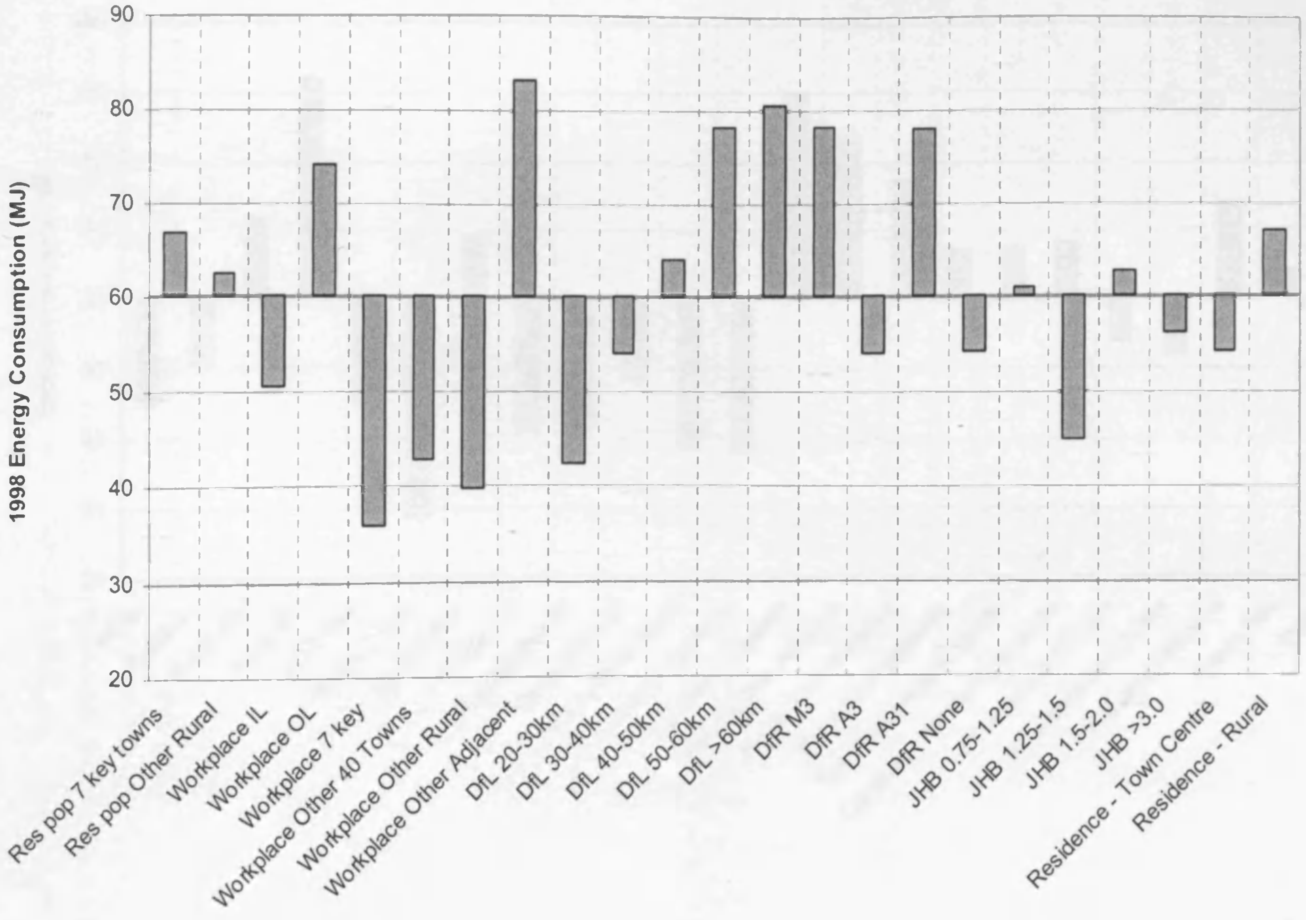
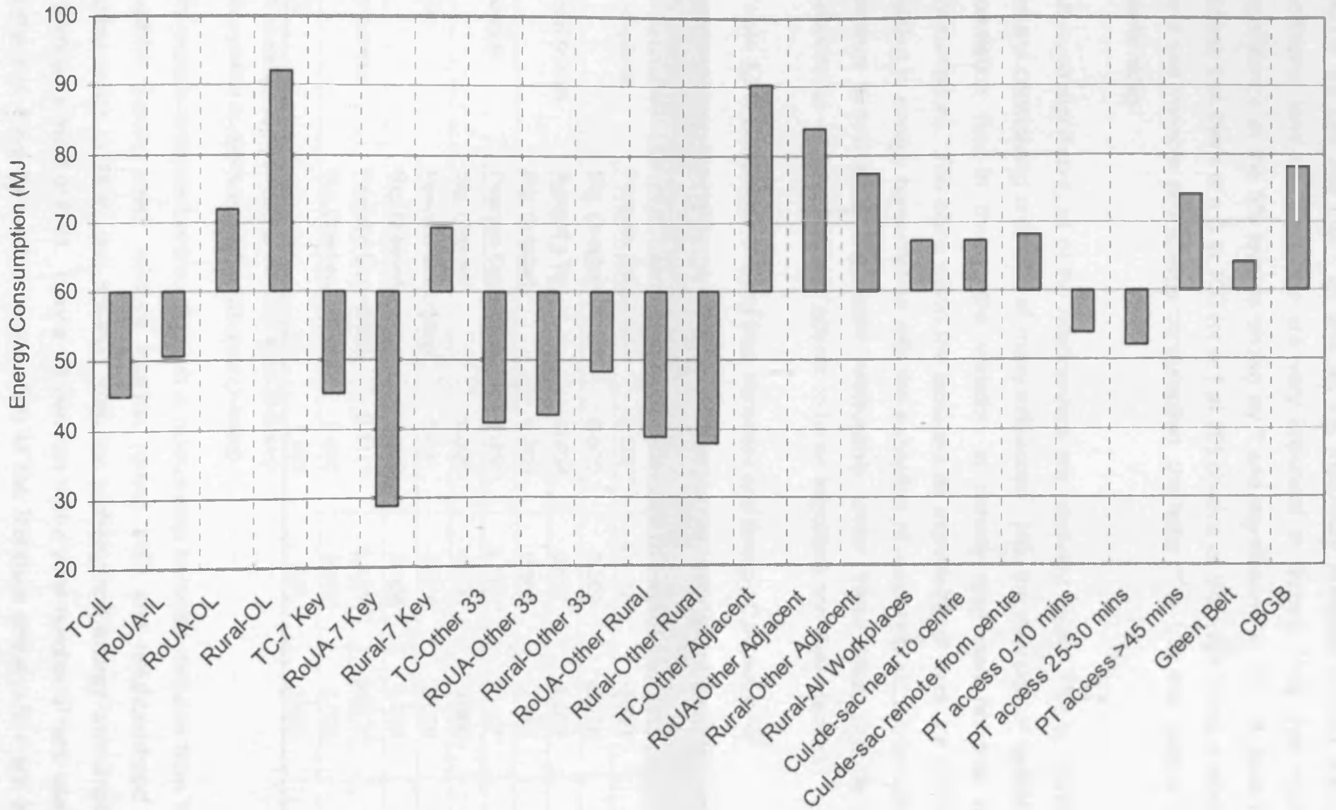


Figure 4.61: *The Land Use High and Low Energy Consumers (At Least +/-10% >Sample Average)*



Correlation Analysis

Correlation analysis gives an indication of the strength of the linear association between variables. Pearson's product moment correlation is used to examine interval data, Kendall's tau for ordinal variables and Chi square is used for nominal data. Tables 4.21-4.22 show correlation factors between the main land use variables and energy consumption in 1998 and 2001. The most highly correlated variables in 1998 and 2001 are residential population density, distance from London and public transport accessibility.

Hence we can see that - as well as the frequently analysed density and travel relationship – additional land use variables are very important in Surrey. Note that within Tables 4.21-4.22 significance at the 5% level is shown by * and significance at the 1% level by **. The former * means that there is a 5 in 100 (or a 1 in 20) chance of there not being a relationship between the land use variable and energy consumption; the latter ** a 1 in 100 chance of there not being a relationship.

Although significant, all of the relationships are relatively weak. This is however to be expected - we are considering only one of many influences. NB. the direction of causation is not proved by correlation (so, in theory, the variation in density may also be due variations in energy consumption). The signs within the table are as expected - all land use variables being positively related to energy consumption with the exception of residential population density. Jobs-housing balance provides no significant relationship under these tests, this reflecting a non-linear relationship – it does however appear to be an important non-linear factor.

Table 4.21: *Correlation of Land Use Variables and Energy Consumption*

Land Use Variable	Correlation	EC98	EC01	JD98	JD01
respopde	Pearson Correlation	-0.132**	-0.132**	-0.058*	-0.071
	Sig. (2-tailed)	0.000	0.002	0.019	0.105
respopsize	Kendall's Tau	-0.024	0.007	0.001	-0.035
	Sig. (2-tailed)	0.300	0.864	0.972	0.428
distlon	Pearson Correlation	0.179**	0.211**	0.143**	0.14**
	Sig. (2-tailed)	0.000	0.000	0.000	0.001
jhb	Pearson Correlation	0.011	-0.005	0.008	0.045
	Sig. (2-tailed)	0.635	0.898	0.733	0.303
ptaccess	Pearson Correlation	0.117**	0.133**	0.073**	0.138**
	Sig. (2-tailed)	0.000	0.002	0.003	0.002
N		1,653	525	1,653	525

***Correlation is significant at the 0.01 level (2-tailed)*

**Correlation is significant at the 0.05 level (2-tailed)*

Chi-square analysis confirms there is a relationship between distance from the highway, resident location (urban area), resident location (green belt) and neighbourhood design and energy consumption in 1998; and distance from the highway and energy consumption in 2001, using a significance level of 0.01. Hence we can see that a wide number of land use variables - including some that have had little consideration in the literature previously - are important in the land use/transport relationship.

Table 4.22: *Chi-Square Tests for Land Use Variables and Energy Consumption*

Chi-Square Test	Value	df	Asymp. Sig. (2-sided)
Distance from Highway-EC98			
Pearson Chi-Square	91.02 [a]	15	0.000**
Likelihood Ratio	97.72	15	0.000
Linear-by-Linear Association	10.12	1	0.001
[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 11.72.			
Distance from Highway-EC01			
Pearson Chi-Square	15.39 [b]	6	0.017*
Likelihood Ratio	15.49	6	0.017
Linear-by-Linear Association	6.46	1	0.011
[b] 0 cells (0%) have expected count less than 5. The minimum expected count is 7.21.			
Resident Location (Urban Area)-EC98			
Pearson Chi-Square	13.57 [c]	4	0.009**
Likelihood Ratio	13.71	4	0.008
Linear-by-Linear Association	9.84	1	0.002
[c] 0 cells (0%) have expected count less than 5. The minimum expected count is 60.87.			
Resident Location (Urban Area)-EC01			
Pearson Chi-Square	15.06 [d]	10	0.130
Likelihood Ratio	16.48	10	0.087
Linear-by-Linear Association	0.12	1	0.734
[d] 0 cells (0%) have expected count less than 5. The minimum expected count is 5.04.			
Resident Location (Green Belt)-EC98			
Pearson Chi-Square	12.17 [e]	4	0.016*
Likelihood Ratio	11.98	4	0.018
Linear-by-Linear Association	11.54	1	0.001
[e] 0 cells (0%) have expected count less than 5. The minimum expected count is 14.52.			
Resident Location (Green Belt)-EC01			
Pearson Chi-Square	4.52 [f]	4	0.340
Likelihood Ratio	4.42	4	0.352
Linear-by-Linear Association	2.91	1	0.088
[f] 0 cells (0%) have expected count less than 5. The minimum expected count is 5.64.			
Neighbourhood Design-EC98			
Pearson Chi-Square	29.30 [g]	10	0.001**
Likelihood Ratio	29.06	10	0.001
Linear-by-Linear Association	10.46	1	0.001
[g] 0 cells (0%) have expected count less than 5. The minimum expected count is 11.40.			
Neighbourhood Design-EC01			
Pearson Chi-Square	4.68 [h]	4	0.322
Likelihood Ratio	4.44	4	0.350
Linear-by-Linear Association	0.91	1	0.339
[h] 0 cells (.0%) have expected count less than 5. The minimum expected count is 10.79.			

N=1,653 in 1998 and 525 in 2001

***Chi-square is significant at the 0.01 level*

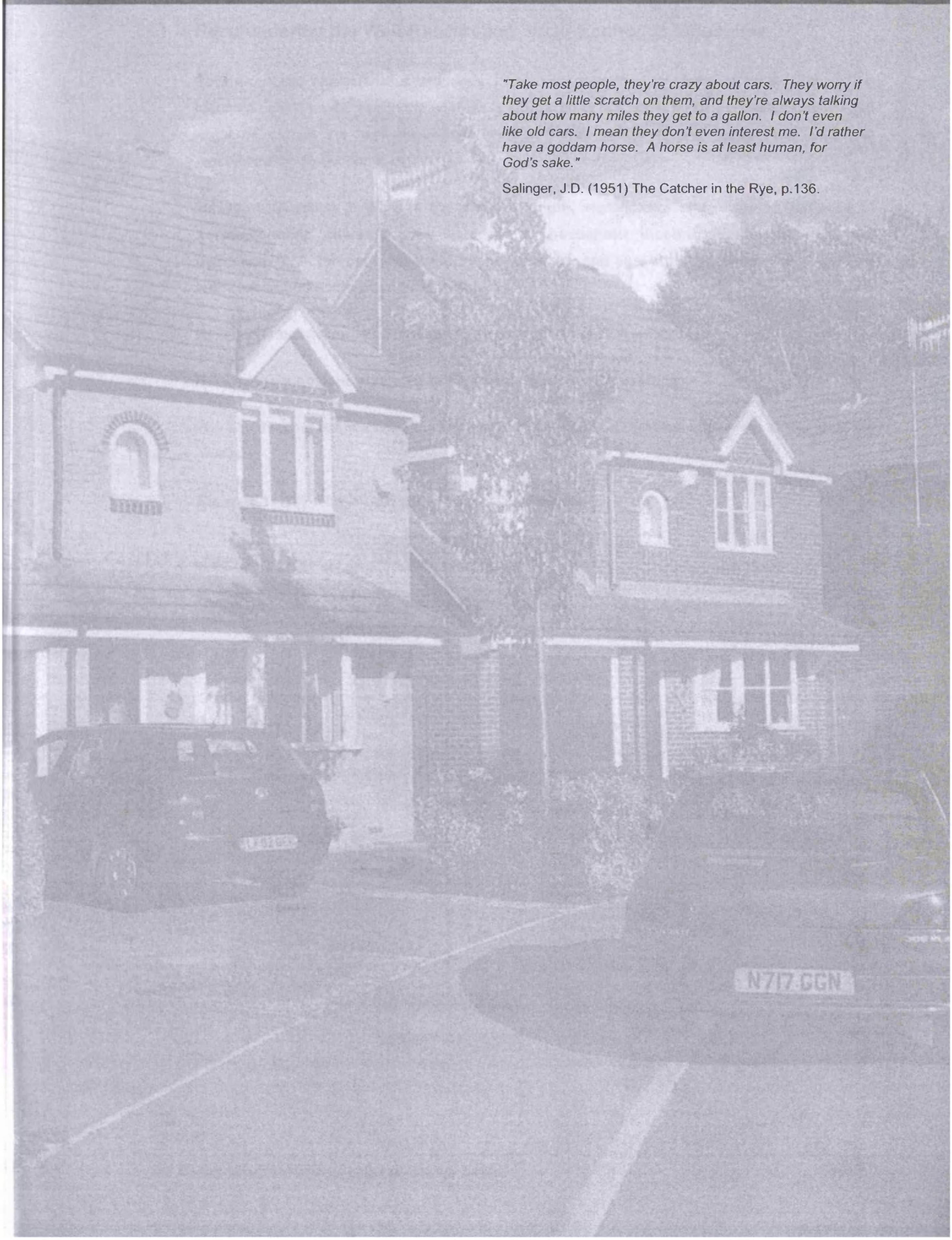
**Chi-square is significant at the 0.05 level*

The important conclusion, therefore, from detailed analysis of travel behaviour in Surrey is that it is possible to understand some apparent logic behind energy consumption in the commute to work. A wide range of land use variables are significantly associated with travel behaviour. At the individual level these are traded against each other, leading to a particular travel pattern. At the aggregate level, land use is a critical structuring feature behind travel behaviour and energy consumption. The importance of this has historically been under estimated, possible because of the difficulty in proving significant relationships and a typical empirical concentration on simple bi-variate analysis. The policy implication here is critical. Urban structure can be influenced over time. Hence urban planning, at the strategic and local levels, becomes a very important tool in seeking to reduce energy consumption arising from travel (at least in travel associated with the journey to work).

05. Socio-Economic Influences on Travel Behaviour

"Take most people, they're crazy about cars. They worry if they get a little scratch on them, and they're always talking about how many miles they get to a gallon. I don't even like old cars. I mean they don't even interest me. I'd rather have a goddam horse. A horse is at least human, for God's sake."

Salinger, J.D. (1951) The Catcher in the Rye, p.136.



5. Socio-Economic Influences on Travel Behaviour

5.1 Reconsidering the Well-Researched Socio-Economic Influences

Socio-economic characteristics are likely to be very important in terms of understanding the rationale behind travel. Again the analysis is structured in two parts: firstly a consideration of what might be termed the "well-researched" socio-economic variables; and second the "less well researched" socio-economic variables.

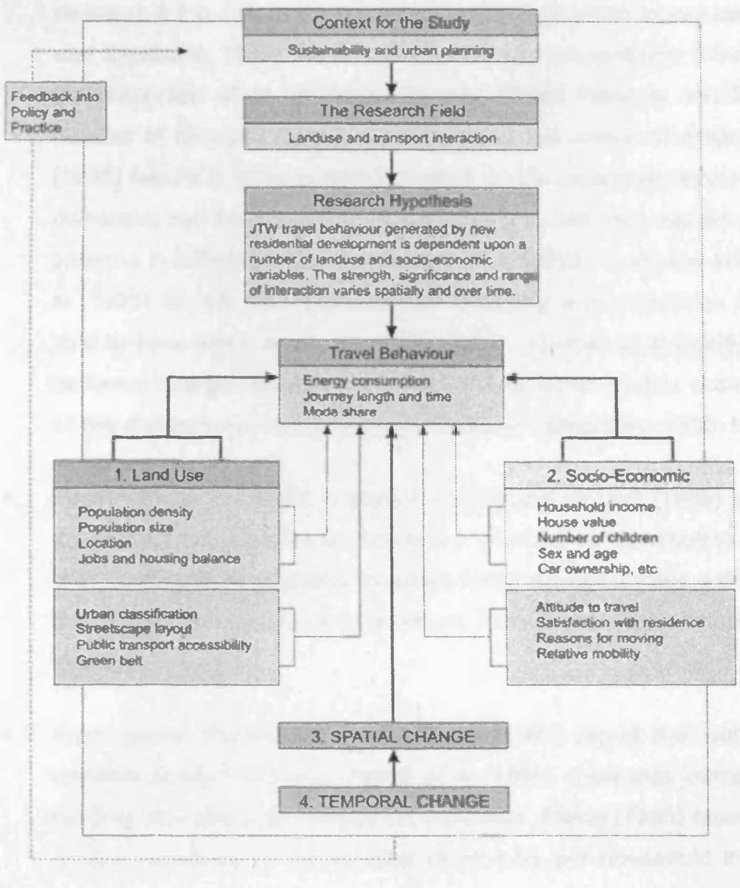
Research Question 3: What is the scale, strength, significance and range of influence of socio-economic characteristics – such as household income, household size, car ownership, children per household, respondent sex and age, etc. – on travel behaviour (the well-researched socio-economic variables).

H_0 – Travel behaviour is not related to socio-economic characteristics.

H_1 – Travel behaviour is related to socio-economic characteristics.

The key diagram below shows the relation of this part of the research to the rest of the empirical analysis.

Figure 5.1: *Well-Researched Socio-Economic Influences*



5.1.1 Income and Car Ownership, Etc.

The literature covering socio-economic influences on travel behaviour is substantial in its own right. Stead (1999) and Stead et al (2000) give a good summary of how socio-economic factors may affect travel patterns; Damm (1982) and Hanson (1982) also provide comprehensive reviews, although the latter two pieces of research are now over 20 years old. The socio-economic factors most often associated with travel behaviour changes are income (household and/or personal), car ownership, work status, gender, age, household size and number of children, and educational attainment. A brief summary of the literature follows, based on Stead (1999):

- Income: increasing household income is linked to trip frequency (Hanson, 1982), with people in higher income households making more journeys than those in lower income households. Also, higher income levels are linked to increased commuting distance (Cervero, 1996a), total distance travelled per person (Naess, 1996), and transport energy consumption (Naess, 1993; Naess et al, 1995). Flannelly and McLeod (1989) show how income is linked to the choice of mode for commuting. Income has also been linked to land use patterns, which may explain some of the variation in travel patterns in different locations. Mogridge (1985) shows how average income in Paris and London rises with increasing distance from the city centre, with the exception of residents in very central locations.

- Car ownership: Hanson (1982) reports that trip frequency increases with car ownership, although Prevedouros and Schofer (1992) contend that car availability does not explain the variation in trip frequency. Travel distance is reported to increase with car ownership (Naess and Sandberg, 1996), as is transport energy consumption (Naess and Sandberg, 1996) and the proportion of car journeys (Naess, 1993a). Flannely and McLeod (1989) show that the number of cars per household is linked to the choice of mode for commuting, whilst Ewing (1995) reports that travel time increases as car ownership levels increase. As with income, car ownership can be linked to land use patterns, and may explain some of the variation in travel patterns in different locations. Gordon et al (1989), Levinson and Kumar (1997) and Naess et al (1995) identify links between car ownership and population density. Higher density areas tend to have lower levels of car ownership. Gordon et al (1989) show car ownership tends to be lower in larger cities in the United States. Other studies show that car ownership increases as the distance from the city centre increases (Mogridge, 1985; Naess and Sandberg, 1996).

- Possession of a driver's license: Flannely and Mcleod (1989) show how the possession of a driver's license is linked to the choice of mode for commuting. People who use the bus are likely to come from households where fewer members have a driver's license. They also report that people who share cars to work are likely to come from households with more licenses than average.

- Work status: Prevedouros and Schofer (1991) report that work status does not explain the variation in trip frequency. Ewing et al (1996) show that journey frequency increases as the number of workers per household increases. Ewing (1995) reports that average travel time per person increases as the number of workers per household increases, reflecting that where there is more than one worker in a household, home location may not be near to the workplace of each person.

- Gender: Hanson (1982) reports no difference in total trip frequency according to gender in Sweden. However, Gordon et al (1989b) report that the frequency of non-work trips is higher for women than men in the United States, and that women have shorter work trips than men, regardless of income, occupation, marital and family status.

- Age: Prevedouros and Schofer (1992) report that age explains some of the variation in trip frequency, although Hanson (1982) finds no difference due to age. Flannelly and McLeod (1989) suggest that age has no significant effect on the choice of mode for commuting. Naess et al (1995) report that transport energy consumption increases with increasing age. Banister et al (1997) report a negative correlation between transport energy consumption and the proportion of children within each survey group.

- Household size: Hanson (1982) suggests that journey frequency increases as household size increases, and Ewing et al (1996) support this. Ewing (1995) report that travel time per person increases as household size increases. Banister et al (1997) report that household size is negatively correlated with transport energy consumption.

- Educational attainment: Flannelly and McLeod (1989) suggest that level of education on a per capita basis has no significant effect on the choice of mode for commuting.

The key issues for this thesis are:

- Is there a relationship between socio-economic factors – such as income, car ownership, work status, gender, age, number of children, household size and educational attainment – and travel behaviour?

- What is the impact of particular socio-economic factors on each of the components of travel behaviour - transport energy consumption, journey length, time and mode share?

EVIDENCE FROM SURREY: SOCIO-ECONOMIC INFLUENCES AND TRAVEL BEHAVIOUR

The review of evidence in Surrey uses a wide number of socio-economic characteristics, wider than discussed above, and is sub-divided below into two sections: household and individual characteristics. Again temporal comparisons are considered in Chapter 6 alongside attrition issues (see page 270 onwards).

Household Characteristics

Table 5.1A: *House Tenure and Travel Behaviour*

House Tenure	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Owner Occupied (Outright)	162	54	52.1	58.4	25.2	27.5	36.9	40.4	78%	71%
Owner Occupied (Mortgage)	1,274	427	64.0	60.5	32.6	30.2	44.7	43.1	73%	68%
Other	217	44	40.2	50.0	18.9	18.9	29.5	26.0	61%	68%
Employer owned	25	5**	46.2	82.9	24.7	23.1	32.2	29.0	43%	33%
Private Rented	77	11*	44.3	47.6	23.3	19.6	39.5	31.7	61%	58%
Public Rented	72	15*	35.5	61.1	12.1	16.8	18.4	21.1	62%	80%
Shared Ownership	34	12*	36.0	24.4	13.7	12.1	21.0	16.7	71%	100%
Not stated	9**	1**	42.9	53.9	40.0	103.5	57.7	132.5	61%	70%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

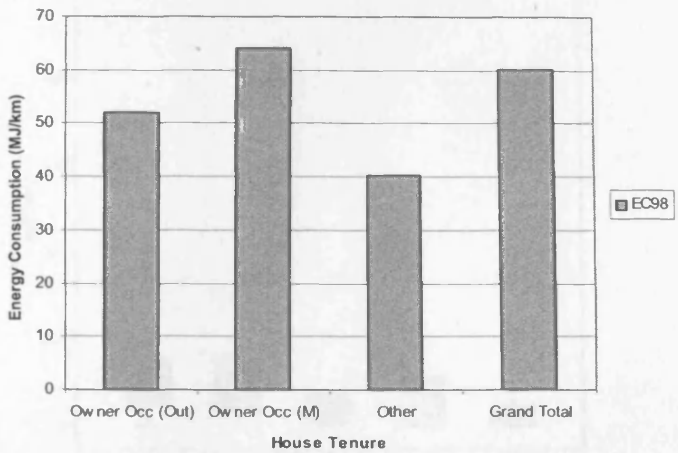
X: 5% > sample average

Y: 5% < sample average

Not surprisingly, the vast majority of respondents are owner occupiers with a mortgage (77% of the sample in 1998 and 81% in 2001). Owner occupied outright is the next largest tenure grouping. A number of patterns are evident:

- The highest energy consumption is found in the owner occupied households with a mortgage (6% higher than the sample average in 1998). Low average energy consumption, journey distance and time and (usually) low car mode shares are found in the other tenure groupings, particularly public rented, private rented and particularly employer owned households.

Figure 5.2: *House Tenure and Energy Consumption*



Chi-square analysis confirms there is a significant relationship between house tenure and energy consumption (in the 1998 data at least).

Table 5.1B: *House Tenure and Travel Behaviour*

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
House Ten-EC98			
Pearson Chi-Square	38.85	4	0.000**
House Ten-EC01			
Pearson Chi-Square	3.32	4	0.505

***Chi-square is significant at the 0.01 level.*

**Chi-square is significant at the 0.05 level.*

Figure 5.3: *House Tenure and Energy Consumption 1998*

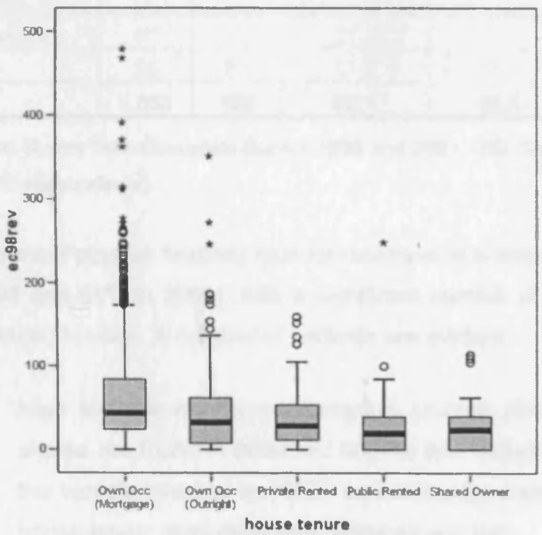


Figure 5.4: *House Tenure and Energy Consumption 2001*

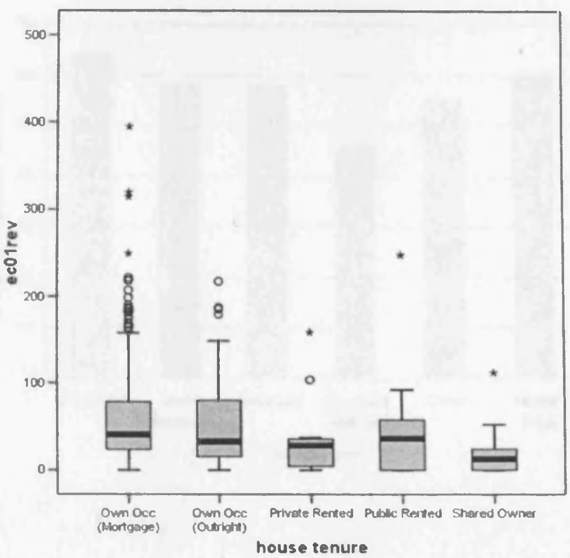


Table 5.2A: *House Type and Travel Behaviour*

House Type	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Detached	814	264	64.3	61.8	33.6	31.8	46.8	46.4	72%	64%
Semi-detached	314	106	58.0	55.0	27.6	27.5	37.2	37.5	73%	67%
Terraced	294	97	57.9	56.5	27.2	24.9	38.1	34.7	75%	76%
Purpose Built Flat	127	30	45.9	59.3	24.8	24.1	36.0	33.4	71%	81%
Other	104	28	55.2	63.0	24.0	28.5	36.8	40.4	69%	66%
Converted Flat	47	12*	53.5	65.8	24.0	28.5	34.3	37.1	66%	73%
Detached bungalow	21	5**	69.9	62.6	35.5	31.2	45.1	43.4	75%	50%
Semi-detached bungalow	3**	3**	55.0	55.0	12.8	12.8	20.9	20.9	67%	67%
Terraced bungalow	1**	-	21.0	-	7.3	-	16.0	-	100%	-
Not stated	32	8**	57.3	71.0	19.9	37.3	38.9	58.2	69%	65%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

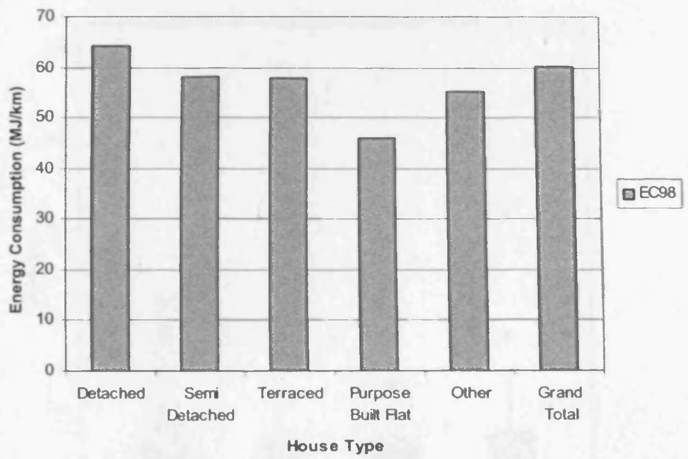
X: 5% > sample average

Y: 5% < sample average

The most popular housing type for residents is a detached house (49% in 1998 and 51% in 2001), with a significant number of semi-detached and terraced houses. A number of patterns are evident:

- High average energy consumption, journey distance and time and (usually) high car mode shares are found in detached houses and detached bungalows, for the former 7% higher than the sample average in 1998. Lower energy consumption patterns are found in the remaining house types: semi-detached, terraced and flats.

Figure 5.5: *House Type and Energy Consumption*



Chi-square analysis confirms there is a significant relationship between house tenure and energy consumption (in the 1998 data at least).

Table 5.2B: *House Tenure and Travel Behaviour*

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
House Typ-EC98			
Pearson Chi-Square	17.71 c	6	0.007**
House Typ-EC01			
Pearson Chi-Square	12.53 d	6	0.051

***Chi-square is significant at the 0.01 level.*

**Chi-square is significant at the 0.05 level.*

Figure 5.6: *House Type and Energy Consumption 1998*

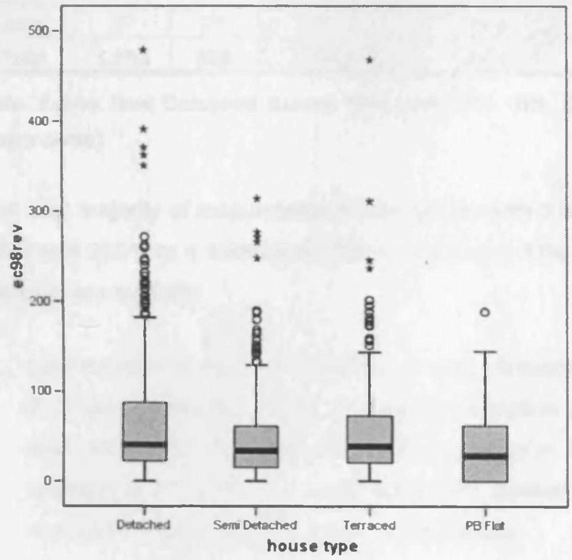


Figure 5.7: *House Type and Energy Consumption 2001*

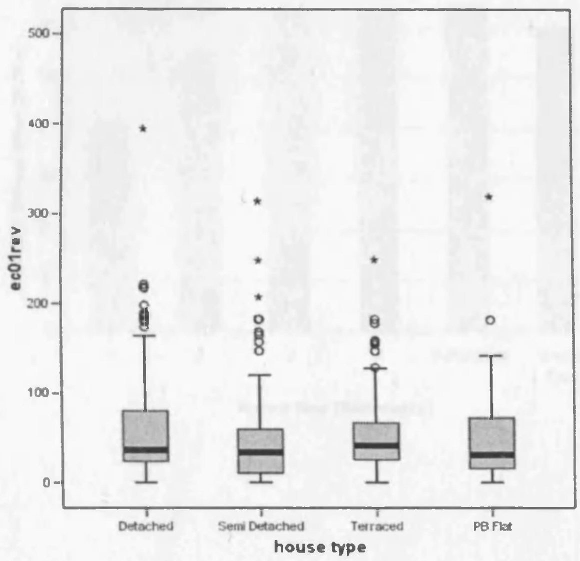


Table 5.3A: *House Size and Travel Behaviour*

Number of Bedrooms	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
1	86	13*	41.0	60.1	17.5	19.5	27.5	26.5	65%	50%
2	338	114	53.7	60.1	26.5	26.5	36.7	36.6	74%	78%
3	560	177	63.3	53.2	29.5	26.4	39.8	38.1	74%	70%
4	470	164	62.3	62.9	33.2	32.7	45.3	45.3	72%	64%
5 and over	199	57	64.3	64.5	36.4	33.5	55.7	53.0	65%	55%
5	191	56	63.6	66.7	36.1	33.7	55.5	53.2	65%	54%
6	5**	-	101.1	-	59.1	-	79.3	-	43%	-
7	3**	1**	49.9	72.2	17.4	25.1	31.8	41.3	100%	100%
Not stated	7**	2**	42.4	70.4	14.7	24.5	22.3	36.0	62%	54%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%

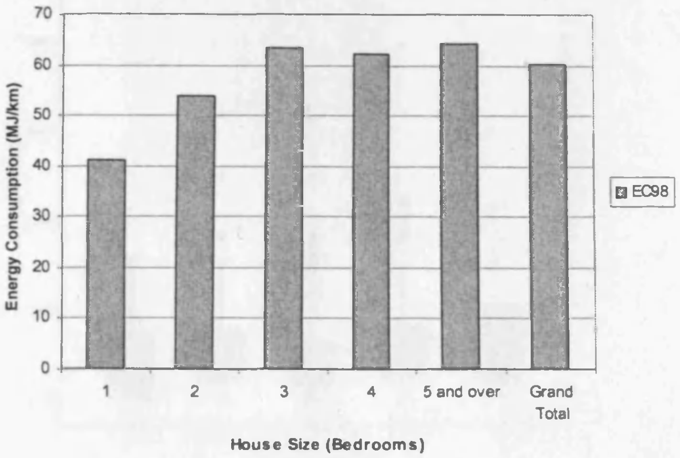
Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key
X: 5% > sample average
Y: 5% < sample average

The vast majority of respondents live in houses with 3 bedrooms (34% in both 1998 and 2001) or 4 bedrooms (28% in 1998 and 31% in 2001). A number of patterns are evident:

- Low average energy consumption, journey distance and times are associated with houses with 2 or less bedrooms; higher energy consumption patterns, journey distance and time with 3 bedrooms (5% more than the sample average in 1998) or 4 or 5 bedrooms and over. There appears to be no simple relationship with number of bedrooms and mode share, although 1 bedroom houses have the lowest mode share.

Figure 5.8: *House Size and Energy Consumption 1998*



Correlation analysis confirms there is a significant relationship between house size and energy consumption and journey distance.

Table 5.3B: *House Size and Travel Behaviour*

Socio-Economic Variable	Correlation	EC98	EC01	JD98	JD01
bedrooms	Pearson Correlation	0.088**	0.070	0.157**	0.128**
	Sig. (2-tailed)	0.000	0.098	0.000	0.003

Figure 5.9: *House Size and Energy Consumption 1998*

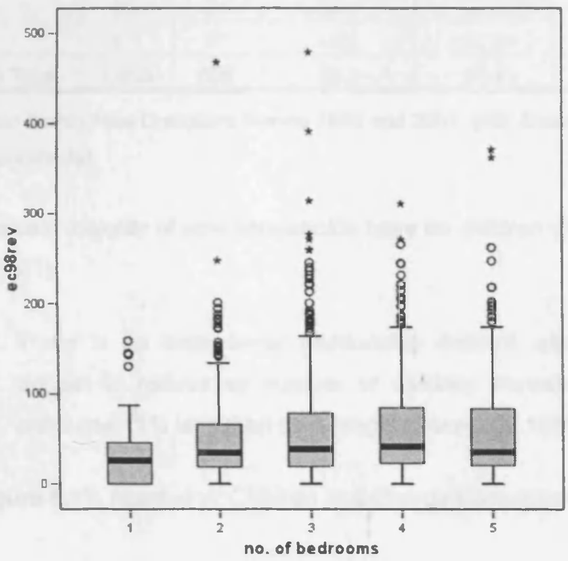


Figure 5.10: *House Size and Energy Consumption 2001*

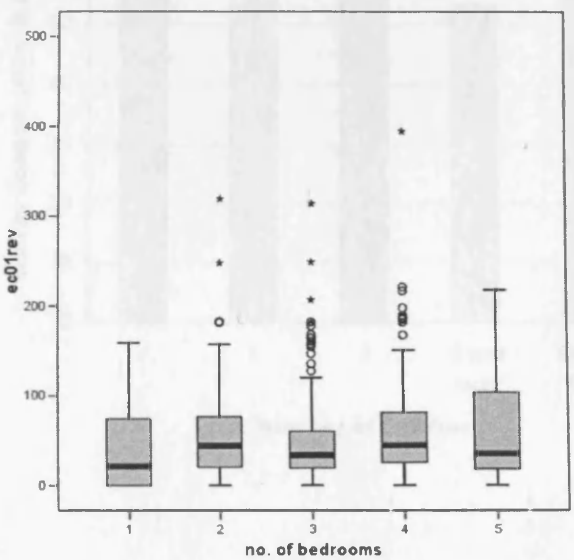


Table 5.4A: *Number of Children and Travel Behaviour*

Number of Children	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
0	1,086	351	60.7	55.3	30.3	29.3	41.6	40.8	72%	69%
1	247	77	60.9	66.3	29.2	39.4	41.6	54.6	74%	59%
2	242	74	58.6	62.6	31.4	37.1	44.5	51.1	71%	69%
3 and over	78	23	53.5	53.6	26.5	33.0	40.7	54.6	74%	73%
3	69	21	54.5	52.8	27.4	40.4	41.7	69.9	77%	56%
4	9**	2**	45.8	54.9	19.7	20.4	33.0	28.3	50%	100%
Grand Total	1,653	525	60.1	59.4	30.1	30.1	41.9	41.9	72%	68%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

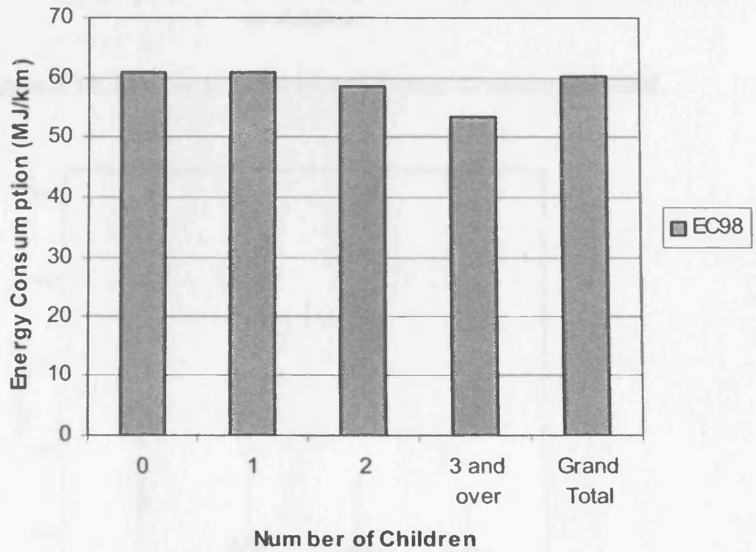
X: 5% > sample average

Y: 5% < sample average

The vast majority of new households have no children (66% in 1998 and 67% in 2001).

- There is no clear linear relationship evident, although average energy consumption does appear to reduce as number of children increases (households with 3 and over children consume 11% less than the sample average in 1998).

Figure 5.11: *Number of Children and Energy Consumption*



Correlation analysis confirms any relationship is weak – there is no significant association between household size and energy consumption.

Table 5.4B: *Number of Children and Travel Behaviour*

Socio-Economic Variable	Correlation	EC98	EC01	JD98	JD01
children	Pearson Correlation	-0.022	0.072	-0.012	0.015
	Sig. (2-tailed)	0.356	0.090	0.622	0.723

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.12: *Number of Children and Energy Consumption 1998*

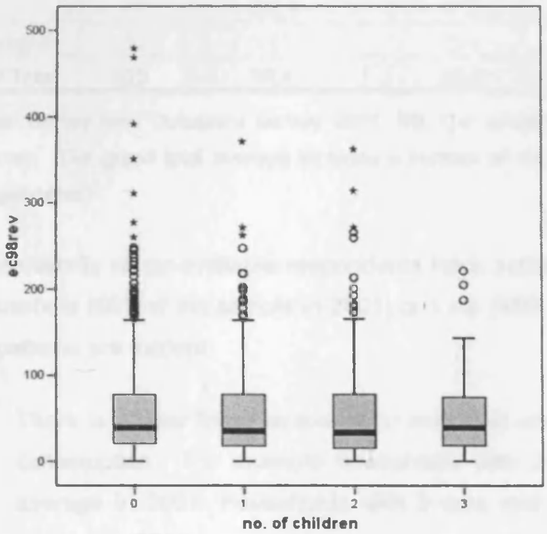


Figure 5.13: *Number of Children and Energy Consumption 2001*

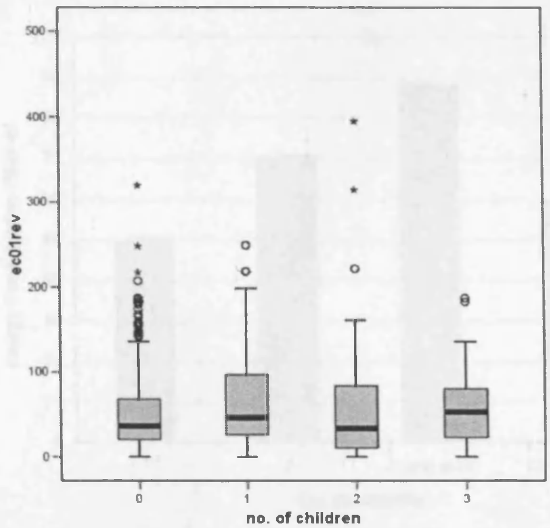


Table 5.5A: *Car Availability and Travel Behaviour*

Car Availability 2001	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
1	95	50.6	30.6	[redacted]	61%
2	157	[redacted]	[redacted]	[redacted]	70%
3 and over	20	[redacted]	[redacted]	[redacted]	[redacted]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Not stated	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Grand Total	525	59.4	29.0	41.4	68%

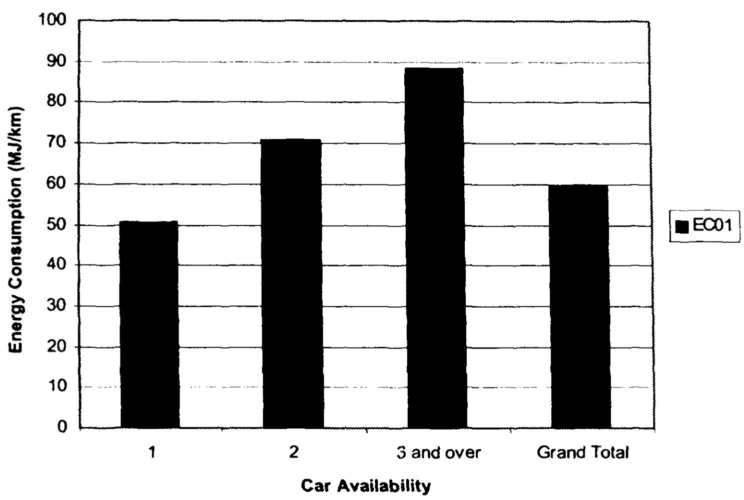
Data: Surrey New Occupiers Survey 2001. NB. Car availability was only available from the 2001 Household Survey. The grand total average includes a number of not stated responses. (NB. Sample size: *<20, **<10 respondents)

Shading Key
■: 5% > sample average
▒: 5% < sample average

The majority of car-available respondents have access to 2 cars in their household (58% of the sample in 2001) or 1 car (35% in 2001). A number of patterns are evident:

- There is a clear linear relationship: increased car availability is associated with higher energy consumption. For example households with 2 cars consume 19% more than the sample average in 2001. Households with 3 cars and over consume 49% more than the sample average in 2001.

Figure 5.14: *Car Availability and Energy Consumption*



Correlation analysis confirms there is a significant relationship between car availability and energy consumption.

Table 5.5B: *Car Availability and Travel Behaviour*

Socio-Economic Variable	Correlation	EC98[37]	EC01	JD98	JD01
caravail	Pearson Correlation	0.134*	0.225**	0.095	0.071
	Sig. (2-tailed)	0.012	0.000	0.086	0.239

Figure 5.15: *Car Availability and Energy Consumption 1998*

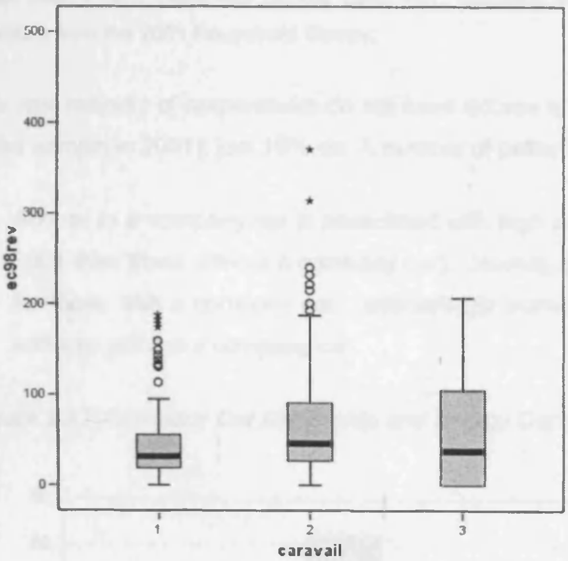
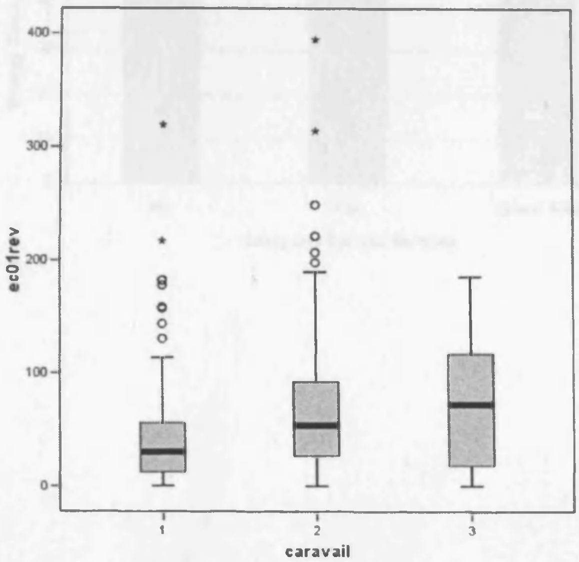


Figure 5.16: *Car Availability and Energy Consumption 2001*



[37] Car availability was only available from the 2001 survey; however is also matched in Table 5.5B and Fig 5.15 to 1998 travel behaviour. A similar approach is taken in other sections where 2001 data is only available (to provide some consistency with the analysis of data elsewhere).

Table 5.6A: *Company Car Ownership and Travel Behaviour*

Company Car Ownership 2001	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
No	422	53.8	28.3	41.4	63%
Yes	100	[redacted]	[redacted]	41.1	[redacted]
Not Stated	[illegible]	37.4	36.3	63.8	56%
Grand Total	525	59.4	29.0	41.4	67%

Data: Surrey New Occupiers Survey 2001. NB. Company car ownership was only available from the 2001 Household Survey.

Shading Key

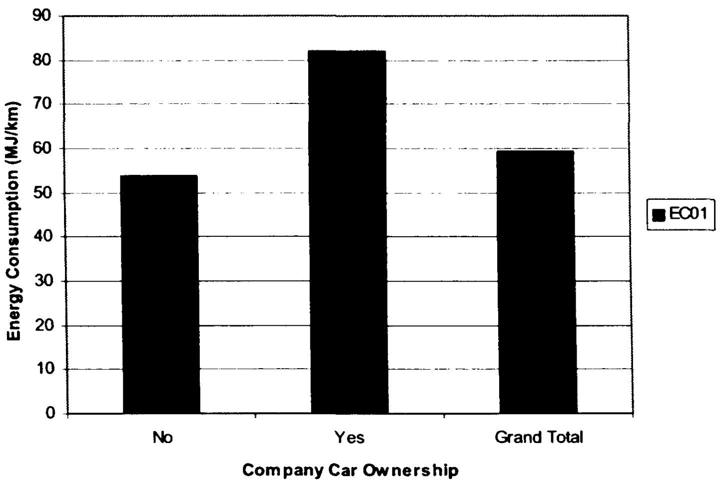
: 5% > sample average

Y: 5% < sample average

The vast majority of respondents do not have access to a company car (80% of the sample in 2001); just 19% do. A number of patterns are evident:

- Access to a company car is associated with high average energy consumption (48% higher in 2001 than those without a company car). Journey distance and car mode shares are all higher for those with a company car. Interestingly journey times are broadly similar between those with and without a company car.

Figure 5.17: *Company Car Ownership and Energy Consumption*



Correlation analysis confirms there is a significant relationship between company car ownership and energy consumption.

Table 5.6B: *Company Car Ownership and Travel Behaviour*

Socio-Economic Variable	Correlation	EC98[38]	EC01	JD98	JD01
compcar	Pearson Correlation	-0.183**	-0.223**	-0.063	-0.071
	Sig. (2-tailed)	0.000	0.000	0.135	0.103

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.18: *Company Car Ownership and Energy Consumption 1998*

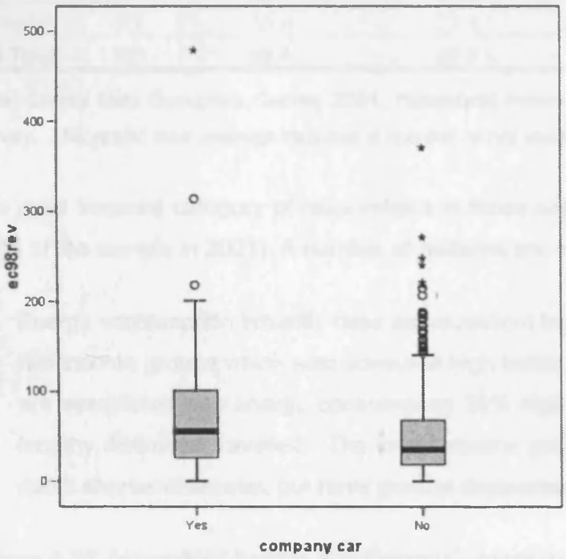
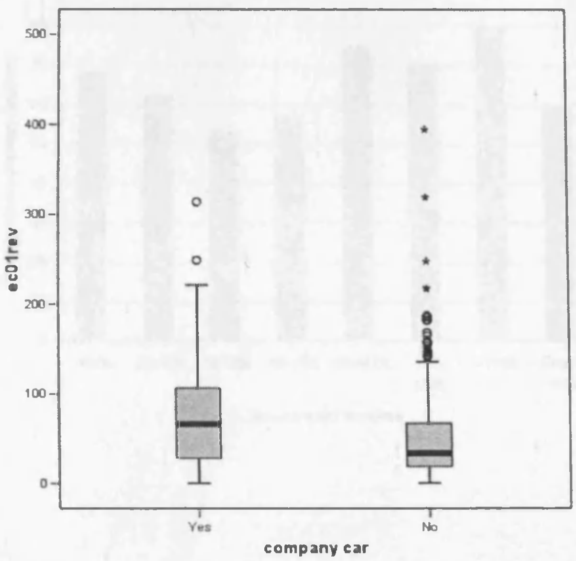


Figure 5.19: *Company Car Ownership and Energy Consumption 2001*



[38] Company car ownership was only available from the 2001 survey; however is also matched here to 1998 travel behaviour.

Table 5.7A: *Household Income and Travel Behaviour*

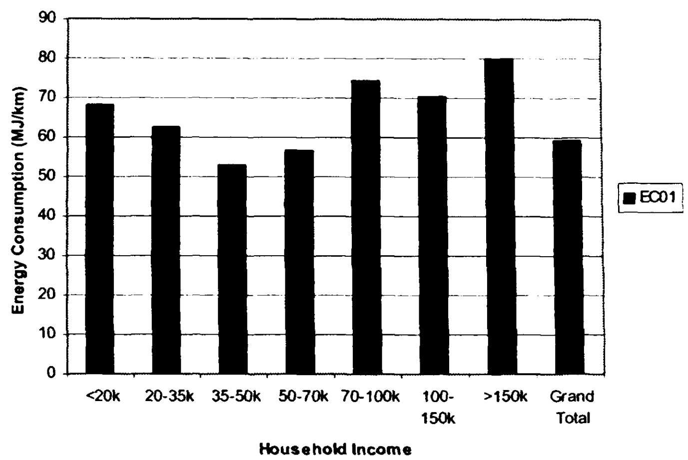
Household Income 2001	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
<20k	23	[redacted]	21.6	30.5	[redacted]
20-35k	56	[redacted]	26.3	32.8	[redacted]
35-50k	82	52.9	25.7	35.3	[redacted]
50-70k	117	56.8	29.9	43.5	69%
70-100k	63	[redacted]	[redacted]	[redacted]	66%
100-150k	31	[redacted]	[redacted]	[redacted]	58%
>150k	24	[redacted]	[redacted]	[redacted]	58%
Not stated	129	48.9	23.4	[illegible]	[illegible]
Grand Total	525	59.4	29.0	41.4	67%

Data: Surrey New Occupiers Survey 2001. Household income was only available from the 2001 Household Survey. The grand total average includes a number of not stated responses.

The most frequent category of respondents is those with a household income between £50k-£70k (22% of the sample in 2001). A number of patterns are evident:

- Energy consumption broadlly rises as household income rises, with the exception of the lowest two income groups which also consume high levels of energy. Household incomes over £150k are associated with energy consumption 35% higher than the sample average – the result of lengthy distances travelled. The lower income groups consuming high levels of energy travel much shorter distances, but have greater dependence on the car.

Figure 5.20: *Household Income and Energy Consumption*



Correlation analysis confirms there is a significant relationship between household income and energy consumption and journey distance.

Table 5.7B: *Household Income and Travel Behaviour*

Socio-Economic Variable	Correlation	EC98[39]	EC01	JD98	JD01
housinco	Pearson Correlation	0.125**	0.123*	0.166**	0.225**
	Sig. (2-tailed)	0.005	0.012	0.000	0.000

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.21: *Household Income and Energy Consumption 1998*

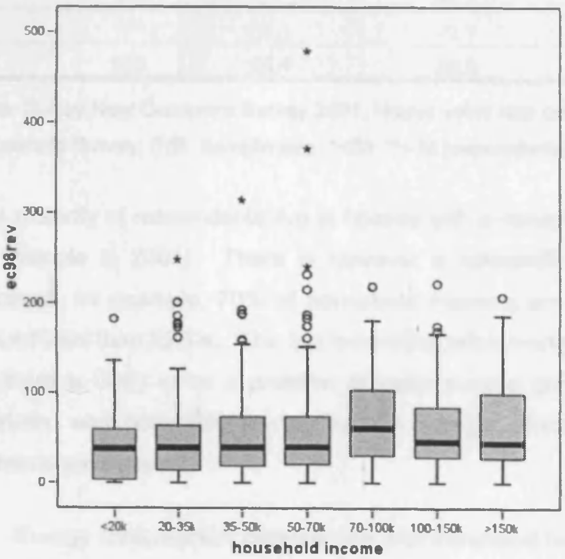
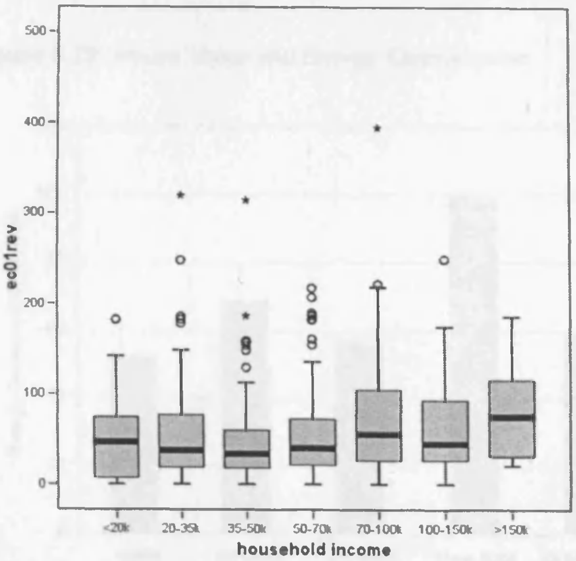


Figure 5.22: *Household Income and Energy Consumption 2001*



[39] household income was only available from the 2001 survey; however is also matched here to 1998 travel behaviour.

Table 5.8A: *House Value and Travel Behaviour*

House Value 2001	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
<£200k	305	51.9	24.0	35.6	70%
£200-£400k	164	68.6	35.9	47.1	71%
£400-£600k	38	57.0	33.1	53.1	46%
>£600k	18*	99.5	42.5	61.8	60%
£600-£800k	7**	121.2	42.2	44.9	67%
£800-£1m	4**	116.2	40.4	64.9	100%
>£1m	7**	68.2	43.9	76.8	33%
Grand Total	525	59.4	29.0	41.4	67%

Data: Surrey New Occupiers Survey 2001. House value was only available from the 2001 Household Survey. (NB. Sample size: *<20, **<10 respondents)

Shading Key

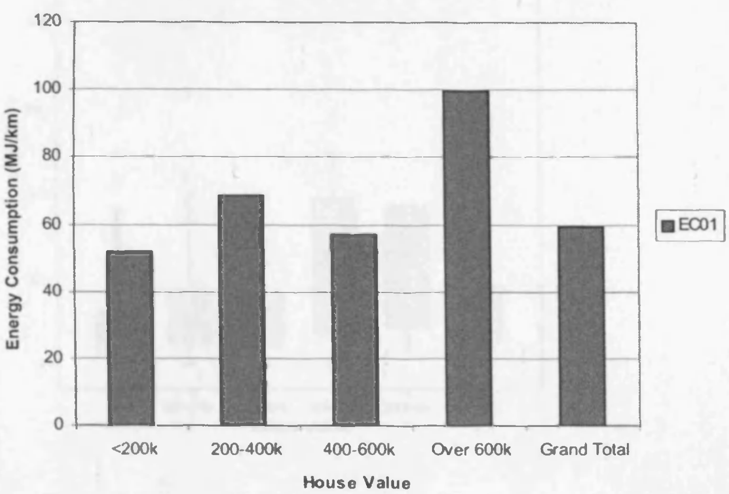
X: 5% > sample average

Y: 5% < sample average

The majority of respondents live in houses with a value less than £200k (58% of the sample in 2001). There is however a mismatch with house values and incomes: for example, 70% of household incomes are below £70k; yet only 58% of houses are valued less than £200k. The income/house price mortgage ratio limit is usually around 3/3.5, and so there is likely to be a problem of lower income groups being priced out of the local housing markets, and potentially having to travel longer distances to work than desired. A number of patterns are evident:

- Energy consumption patterns rise with increased house value, with the exception of the £400-600k cohort. House values >£600k consume 68% higher than the sample average. This high energy consumption is mainly a function of longer travel distances. The house value bracket of £200-400k also consumes more than the sample average.

Figure 5.23: *House Value and Energy Consumption*



Correlation analysis confirms there is a weak relationship between house value and energy consumption (in the 2001 data).

Table 5.8B: *House Value and Travel Behaviour*

Socio-Economic Variable	Correlation	EC98[40]	EC01	JD98	JD01
houseval	Pearson Correlation	0.087	0.109*	0.111	0.107
	Sig. (2-tailed)	0.081	0.046	0.033	0.059

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.24: *House Value and Energy Consumption 1998*

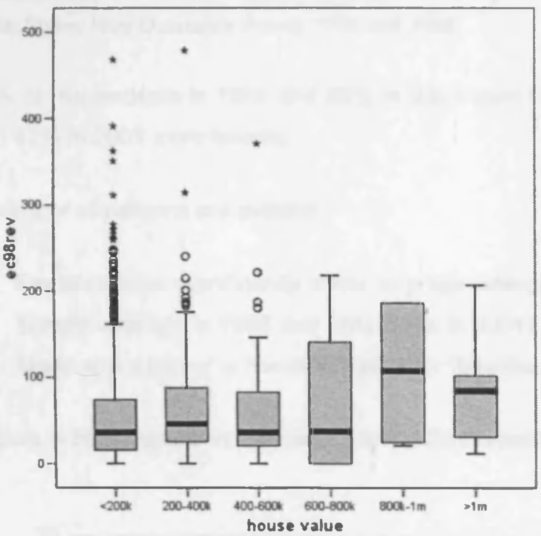
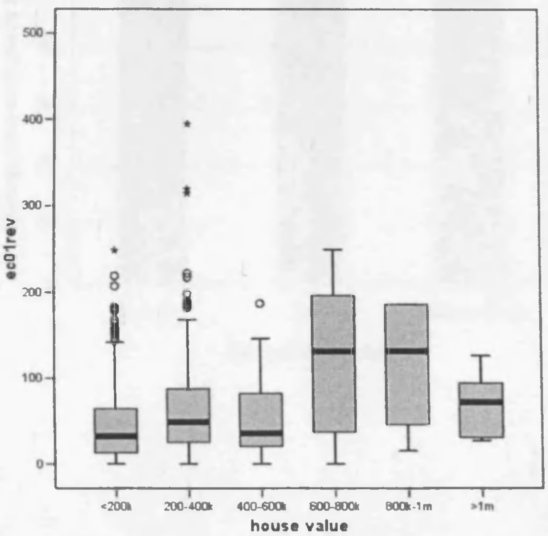


Figure 5.25: *House Value and Energy Consumption 2001*



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[40] House value was only available from the 2001 survey; however is also matched here to 1998 travel behaviour.

Individual Characteristics

Table 5.9A: *Respondent Sex and Travel Behaviour*

Respondent Sex	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Female	707	189	54.1	49.0	25.5	23.1	35.6	33.6	76%	70%
Male	935	274	64.7	64.2	33.7	31.7	47.0	45.2	69%	68%
Not stated	11*	62	49.4	69.0	16.1	35.9	22.2	49.4	70%	69%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	69%

Data: Surrey New Occupiers Survey 1998 and 2001.

Shading Key

X: 5% > sample average

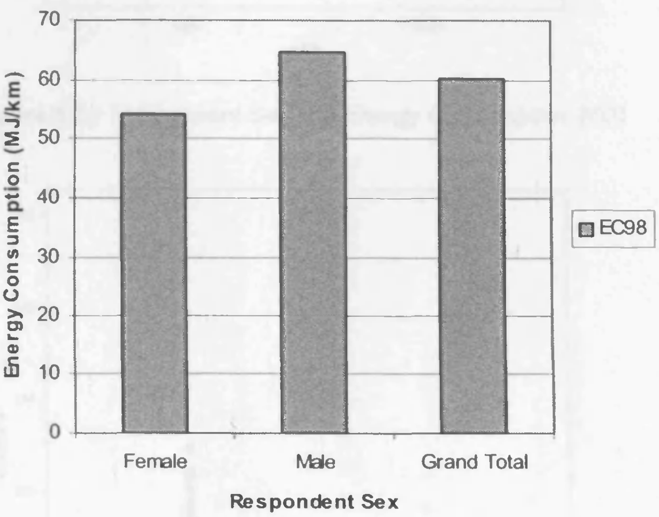
Y: 5% < sample average

57% of respondents in 1998 and 52% in 2001 were male; 36% in 1998 and 42% in 2001 were female.

A number of patterns are evident:

- Females have significantly lower average energy consumption patterns (10% lower than the sample average in 1998 and 18% lower in 2001), a result of shorter journey distance and time. Mode share by car is however higher for females.

Figure 5.26: *Respondent Sex and Energy Consumption*



Correlation analysis confirms there is a strong relationship between respondent sex and energy consumption and journey distance (in the 1998 and 2001 data).

Table 5.9B: *Respondent Sex and Travel Behaviour*

Socio-Economic Variable	Correlation	EC98	EC01	JD98	JD01
sex	Pearson Correlation	-0.068**	-0.147**	-0.158**	-0.182**
	Sig. (2-tailed)	0.004	0.001	0.000	0.000

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.27: *Respondent Sex and Energy Consumption 1998*

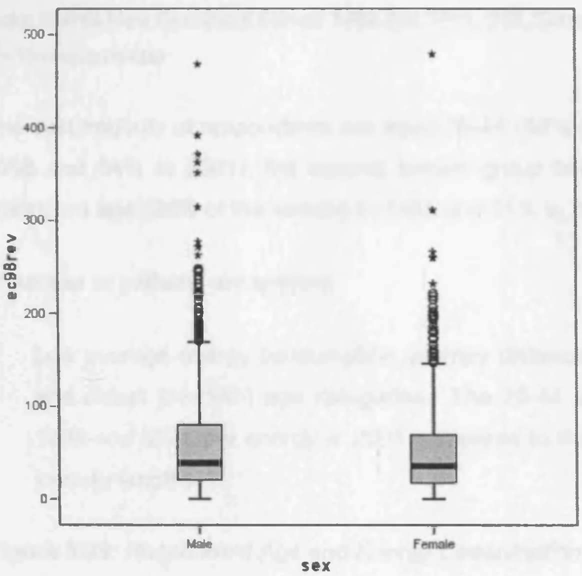


Figure 5.28: *Respondent Sex and Energy Consumption 2001*

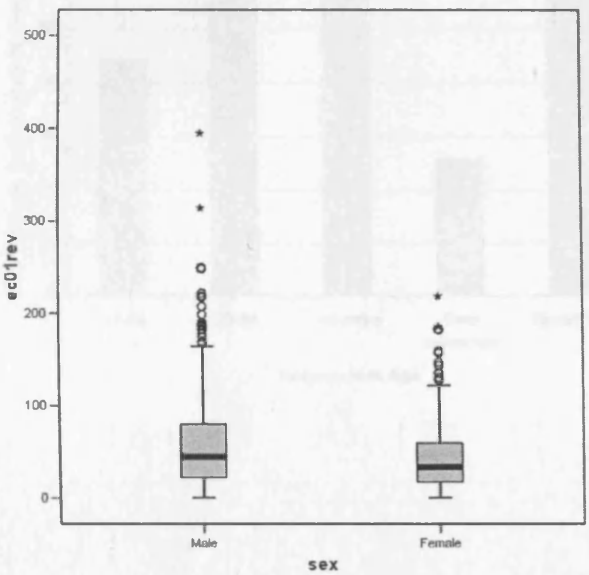


Table 5.10A: *Respondent Age and Travel Behaviour*

Respondent Age	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
17-24	92	14*	44.1	31.2	19.4	15.1	28.6	24.3	65%	64%
25-44	1,120	336	62.1	62.4	31.6	31.1	43.6	43.3	72%	67%
45-retire	422	163	59.4	57.0	28.6	25.8	40.5	38.6	73%	69%
Over retirement	10*	10*	25.8	32.2	16.9	29.5	27.7	42.5	93%	73%
Not stated	9**	2**	53.9	88.8	32.8	30.9	56.5	43.7	89%	50%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

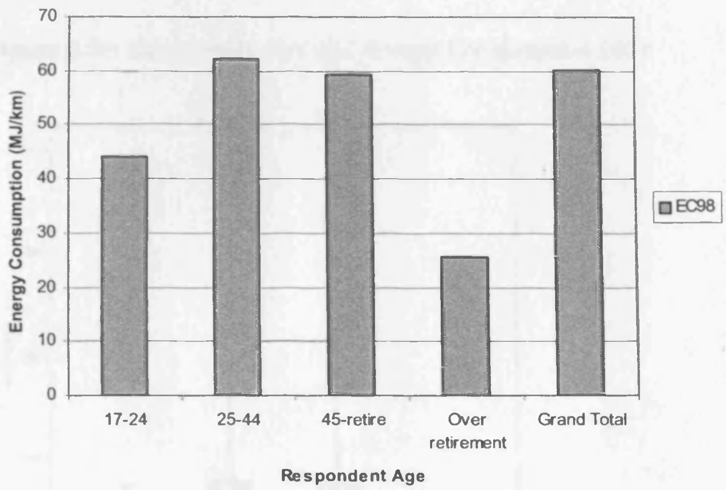
Y: 5% < sample average

The vast majority of respondents are aged 25-44 (68% of the sample in 1998 and 64% in 2001); the second largest group being those 45 to retirement age (26% of the sample in 1998 and 31% in 2001).

A number of patterns are evident:

- Low average energy consumption, journey distance and time is found in the youngest (17-24) and oldest (over 45) age categories. The 25-44 age category consume 3% more energy in 1998 and 5% more energy in 2001 compared to the sample average; mainly a result of longer journey lengths.

Figure 5.29: *Respondent Age and Energy Consumption*



Correlation analysis suggests there is no significant relationship between respondent age and energy consumption. The 25-44 year age group does however consume more energy in their commute to work than the sample average (correlation analysis does not pick this non-linear relationship up).

Table 5.10B: *Respondent Age and Travel Behaviour*

Socio-Economic Variable	Correlation	EC98	EC01	JD98	JD01
age	Pearson Correlation	0.004	-0.043	0.007	-0.045
	Sig. (2-tailed)	0.877	0.319	0.787	0.304

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.30: *Respondent Age and Energy Consumption 1998*

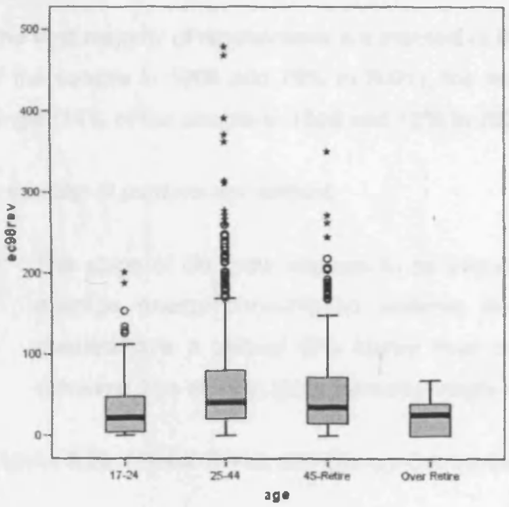


Figure 5.31: *Respondent Age and Energy Consumption 2001*

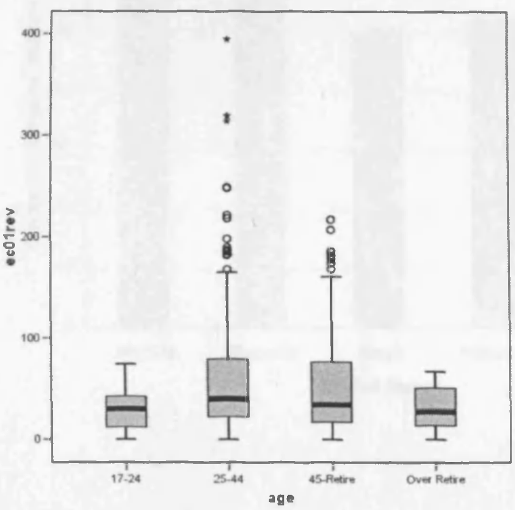


Table 5.11A: *Marital Status and Travel Behaviour*

Marital Status	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Married/partner	1,278	414	62.0	61.1	31.4	29.6	43.4	42.0	72%	67%
Divorced/separated	117	40	59.2	60.3	27.5	23.9	38.4	35.2	83%	72%
Single	238	62	50.5	48.5	25.4	29.7	37.3	43.0	68%	67%
Widowed	18*	7**	52.1	28.1	18.1	9.8	25.2	16.1	95%	75%
Not Stated	2**	3**	54.8	103.0	19.1	35.8	19.0	44.1	50%	67%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

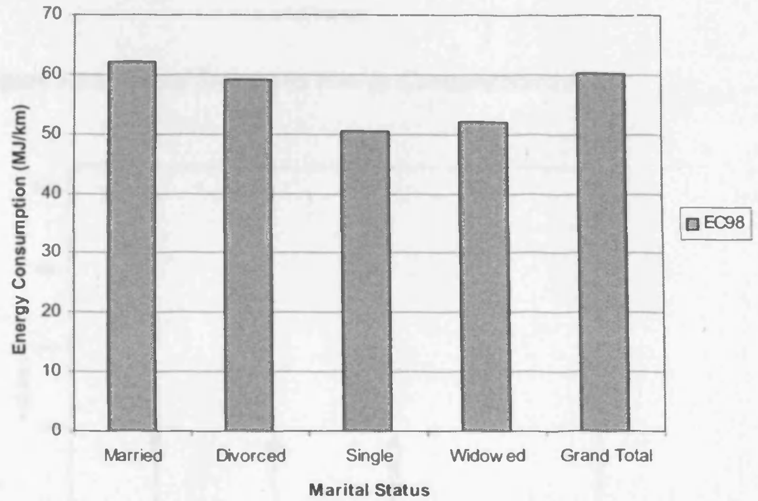
Y: 5% < sample average

The vast majority of respondents are married or living with a partner (77% of the sample in 1998 and 79% in 2001), the next major category being single (14% of the sample in 1998 and 12% in 2001).

A number of patterns are evident:

- The stage of life cycle appears to be important in influencing travel behaviour. The highest average energy consumption patterns and journey distances are from those that are married/have a partner (3% higher than the sample average in 1998). All other cohorts consume less energy; most markedly single and widowed respondents.

Figure 5.32: *Marital Status and Energy Consumption*



Correlation analysis suggests that any relationships are weak between marital status and energy consumption.

Table 5.11B: *Marital Status and Travel Behaviour*

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
Marital-EC98			
Pearson Chi-Square	4.43	4	0.351
Marital-EC01			
Pearson Chi-Square	6.41	4	0.171

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.33: *Marital Status and Energy Consumption 1998*

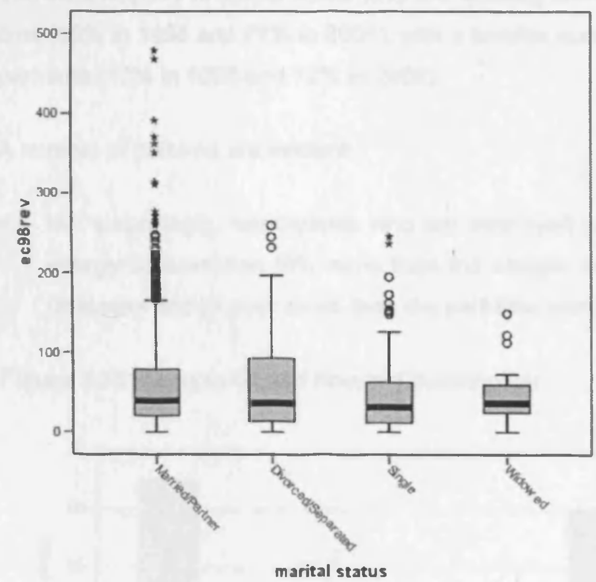


Figure 5.34: *Marital Status and Energy Consumption 2001*

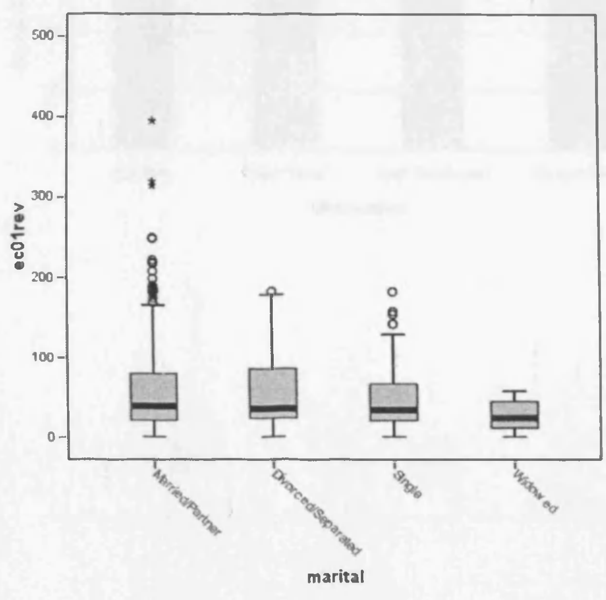


Table 5.12A: *Occupation and Travel Behaviour*

Occupation	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car Driver	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Employed Full Time	1,357	406	65.2	61.3	32.2	30.7	44.6	44.0	71%	69%
Employed Part Time	164	65	38.5	43.8	14.9	18.4	22.3	26.6	78%	74%
Self Employed	125	42	38.6	65.1	26.7	29.6	38.3	40.4	72%	70%
Other	7**	12*	70.2	54.6	38.6	26.0	52.8	35.1	86%	83%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	70%

Data: Surrey New Occupiers Survey 1998 and 2001.

Shading Key

X: 5% > sample average

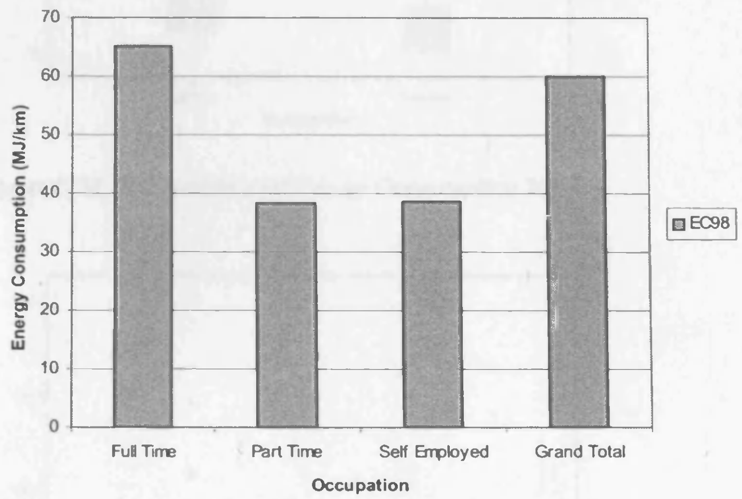
Y: 5% < sample average

The vast majority of respondents who are working are employed full-time (82% in 1998 and 77% in 2001), with a smaller number employed part-time (10% in 1998 and 12% in 2001).

A number of patterns are evident:

- Not surprisingly, respondents who are employed full time are associated with higher average energy consumption (8% more than the sample average in 1998); a result of longer journey distances and journey times than the part-time workers.

Figure 5.35: *Occupation and Energy Consumption*



Correlation analysis confirms there is a significant relationship between occupation and energy consumption (in the 1998 data).

Table 5.12B: *Occupation and Travel Behaviour*

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
Occup-EC98			
Pearson Chi-Square	19.86	2	0.000**
Occup-EC01			
Pearson Chi-Square	3.21	4	0.524

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.36: *Occupation and Energy Consumption 1998*

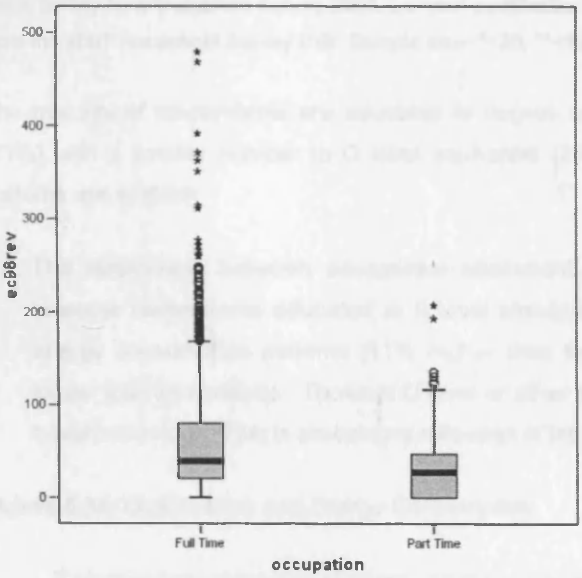


Figure 5.37: *Occupation and Energy Consumption 2001*

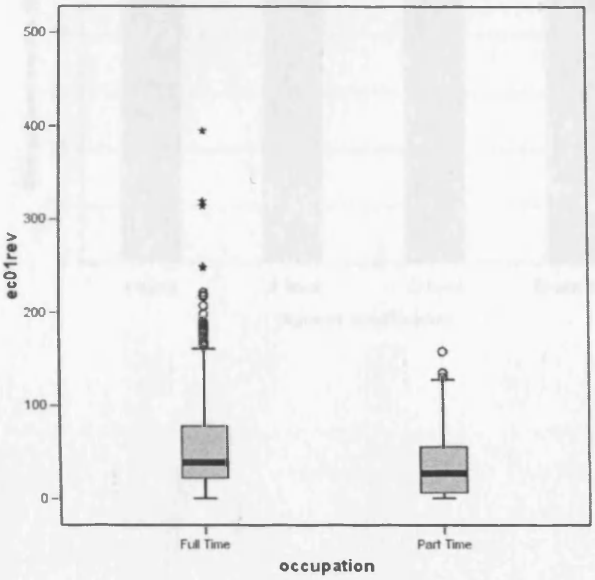


Table 5.13A: *Highest Level of Qualification and Travel Behaviour*

Qualification 2001	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
Degree or Higher	269	61.2	30.5	42.9	66%
A level	69	65.9	35.6	50.7	68%
O level	139	52.3	25.2	37.0	69%
Other	23	58.8	25.8	38.0	69%
None	19	60.7	18.6	24.9	77%
Not Stated	6	61.3	21.3	29.3	20%
Grand Total	525	59.4	29.0	41.4	68%

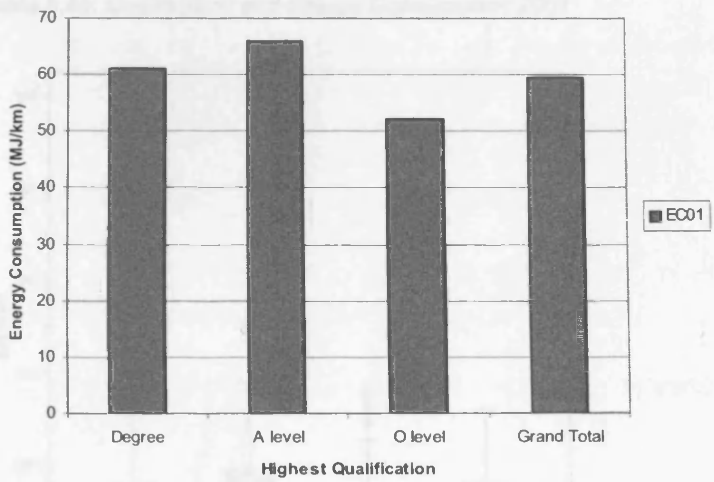
Data: Surrey New Occupiers Survey 2001. Level of qualification was only available from the 2001 Household Survey (NB. Sample size: *<20, **<10 respondents)

Shading Key
X: 5% > sample average
Y: 5% < sample average

The majority of respondents are educated to degree or higher standard (51%) with a smaller number to O level equivalent (26%). A number of patterns are evident:

- The relationship between educational attainment and travel behaviour is not overly clear, however respondents educated to A level standard are associated with the highest average energy consumption patterns (11% higher than the sample average in 2001); a function of longer journey distance. Those at O level or other standards have the least energy consuming travel behaviour. This is probably a reflection of income levels and type of employment.

Figure 5.38: *Qualification and Energy Consumption*



Correlation analysis confirms that any reationships are weak between qualification and energy consumption.

Table 5.13B: *Qualification and Travel Behaviour*

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
Qualif-EC98[41]			
Pearson Chi-Square	9.01	6	0.173
Qualif-EC01			
Pearson Chi-Square	4.06	6	0.668

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed).

Figure 5.39: *Qualification and Energy Consumption 1998*

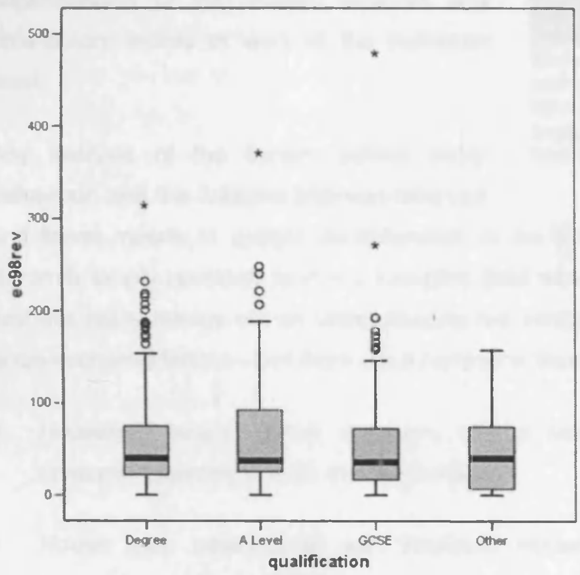
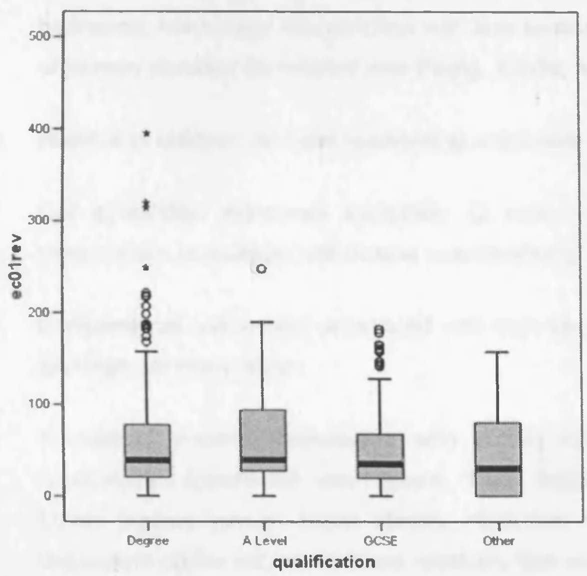


Table 5.40: *Qualification and Energy Consumption 2001*



[41] Qualification was only available from the 2001 survey; however is also matched here to 1998 travel behaviour

5.1.2 Socio-Economic Influences: Conclusions

We can see that the socio-economic/travel behaviour relationship is also incredibly complex. Our improved understanding of travel behaviour in Surrey – and the reasoning behind it – suggests that there are a multitude of socio-economic factors which are significantly associated with energy consumption, distance, time and mode. To understand the aggregate trends requires an understanding of the detailed nuances and contributory factors at work at the individual level.

Socio-economic factors also influence commuting patterns; and to a larger extent than land use factors. Household tenure, household size, household income and car availability are all important influences (Affluent suburbia in Woking).

Any analysis of the factors behind travel behaviour, and the linkages between land use and travel, needs to include consideration of socio-economic factors. Much of the previous literature simply considers land use variables (and most frequently just one of these, e.g. density) and this really misses out on understanding the complexity of interactions. Particularly important socio-economic factors - and there are a number of these - are outlined below:

- Household tenure: owner occupiers with a mortgage are associated with high energy consuming journey to work travel behaviour.
- House type: respondents with detached houses are associated with the high energy consuming patterns, with lower consumption in semi-detached, terraced houses and flats.
- House size: high energy consumption is found for respondents in houses with 4 or more bedrooms; low energy consumption with less bedrooms, the difference mainly being a function of journey distance (consistent with Ewing, 1995a; and Banister, 1997a).
- Number of children: no clear relationship with travel.
- Car availability: increased availability (2 cars or over) is associated with higher energy consumption (consistent with Naess and Sandberg, 1996).
- Company car ownership: associated with high energy consumption, longer journey distances and high car mode share.
- Household income: households with higher incomes are associated with high energy consumption (consistent with Hanson, 1982; Naess, 1993a and 1995; and Cervero, 1996a). Lower income groups travel shorter distances in their commute to work, but are more dependent on the car, hence have relatively high energy consumption patterns.
- House value: energy consumption rises with house values over £200k. There is a clear income/house value mismatch in Surrey.

- Respondent sex: males are the higher energy consumers relative to females, with longer commute distances; females are more reliant on the car (consistent with Gordon, 1989).

- Respondent age: the 25-44 age group is associated with the highest energy consumption and the longest journey distances in the commute to work (consistent with Prevedouros and Schofer, 1992; and broadly with Naess, 1995).

- Occupation: full-time employees have higher energy consumption patterns than part timers, with longer journey distances.

Thus a huge number of factors are at work. This thesis is useful in bringing together a wide range of these - a wider review than found in much of the previous literature - and attempting to understand the relationships between land use and socio economic characteristics and travel. Chapter 7 picks up and develops this discussion, and takes it further in terms of considering the relative weight of importance - particularly whether socio-economic factors, and, if so, which ones - are more important than land use factors in determining travel behaviour. Next however, wider socio-economic influences are considered - 'wider' in terms of socio-economic variables that are not usually considered as part of the argument.


Individual characteristics - such as respondent sex and age and occupation - all have an influence on travel behaviour.

5.2 Wider Socio-Economic Influences

The second part of this chapter considers wider socio-economic influences on travel, variables that have typically been "under researched" in the previous literature. These include attitudinal dimensions, and a more detailed analysis of surrounding levels of mobility and dual-income households.

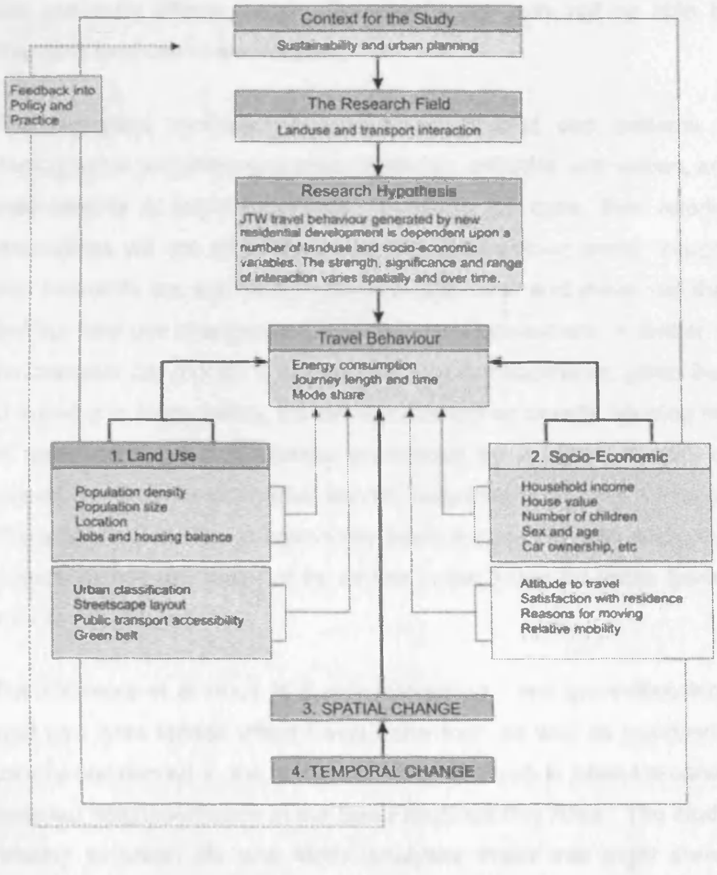
Research Question 4: What is the scale, strength, significance and range of influence of further socio-economic characteristics – such as attitude to travel, surrounding levels of mobility, excess commuting and dual-income households – on travel behaviour (the under-researched socio-economic variables).

H_0 – Travel behaviour is not related to socio-economic characteristics.

H_1 – Travel behaviour is related to socio-economic characteristics.

The key diagram below shows the relation of this part of the research to the rest of the empirical analysis.

Figure 5.41: *Wider Socio-Economic Influences*



5.2.1 Attitudes to Travel

A number of socio-economic characteristics are not traditionally considered as important in the land-use and transport interaction field. These include the cultural dimension and attitudes to travel. Where these issues have been examined in the literature, they have rarely been considered alongside land-use variables.

Cultural and behavioural influences - such as individuals' attitudes to travel – have, for example, received very little attention in terms of their impact on travel behaviour patterns. One notable exception is a study in the US authored by Kitamura, Mokhtarian and Laidet (1997). This examines the influence of attitudinal (and land use) characteristics on travel behaviour for five San Francisco Bay area neighbourhoods. Kitamura et al refer to the evidence on the association between land use and travel and the research tendency to infer causality on the basis of observed association, together with the 'conjecture' that land use policies can be deployed to curb travel demand, in particular car use. They ask whether the observed association between land use and travel is real, or an artefact of the association between land use and a multitude of demographic, socio-economic and transportation supply characteristics which are also associated with travel. For example, high density in general means smaller housing units, lower car ownership levels, smaller household sizes, a mixture of land use types, higher accessibility to facilities and better public transport services. An apparent association between land use and travel, therefore, may not imply that land use genuinely affects travel. Importantly, we may not be able to change travel behaviour by changing land use characteristics.

The argument continues: certain types of land use patterns attract residents with certain demographic and socio-economic attributes, attitudes and values, and these attributes are the 'true' determinants of travel behaviour. If this is the case, then altering land use characteristics by themselves will not affect residents' travel behaviour; travel characteristics will only change after new residents are attracted to the new land uses and move into the area, while old residents who find the land use changes unacceptable move elsewhere. A further caveat is given for advocates of the compact city model: in the case of new developments, given the increasingly unaffordable cost of housing in many areas, the demand for higher density housing may be, for many people, due to its lower cost, not to a lifestyle preference for a higher density environment. If this is so, the selection of a home in a higher density neighbourhood may not be accompanied by the same travel characteristics that have historically been associated with such residential locations. That is, car ownership and use may not be as low in the future for these types of developments as has been the case in the past.

The Kitamura et al study is a very interesting - and groundbreaking - attempt to analyse whether land use does indeed affect travel behaviour, as well as incorporate wider attitudinal aspects not usually considered in the literature. The research is based around a survey of households in five selected neighbourhoods in the San Francisco Bay Area. The study uses 39 attitudinal statements relating to urban life and factor analyses these into eight summary attitudinal variables: pro-environment, pro-transit, suburbanite, automotive mobility, time pressure, urban villager, traffic management and workaholic. These variables are then regressed against the number and proportion of trips by various modes. Measures of residential density, public transport accessibility, mixed land use and the presence of sidewalks are used as neighbourhood and socio-economic characteristics and also regressed against travel behaviour. The research findings reveal that attitudinal variables are more strongly associated with variations in travel than land use characteristics. The implication of the research being that land use policies promoting higher densities and mixes may not alter travel demand materially unless residents' attitudes are also changed.

In a related vein, Prevedorous (1992) considers personality characteristics, residential location and travel patterns. The study finds that 'extroverts' tend to make more non-work trips than 'introverts', that 'materialists' tend to devote a higher proportion of their incomes to owning automobiles than 'utilitarian' respondents, and that 'urbanites' are more likely to live in higher density areas than respondents having personality traits more commonly associated with 'suburban living'. Anable (2005) similarly segments the travel market into particular travel types, including 'aspiring environmentalists' and complacent car addicts'. Urry (2000) tackles travel and mobility from the sociologist angle, assessing the psychological dimensions behind car use and wider travel.

In the UK, Jones et al (1983), Jones (1993 and 1997) and Westminster University (1998) have considered the attitudinal side of travel behaviour and looked at good practice in developing awareness travel campaigns. Jones argues that attitude is an important part of the traffic demand management debate and that raising awareness is potentially one of the 'first steps' in changing travel behaviour. Hence there is a linkage to the Kitamura thinking - yet not the direct comparison in terms of the likely influence of land use versus attitudinal variables on travel.

Finally, a number of researchers have queried the usefulness of land use planning in reducing travel in the context of counter-urbanisation trends and supposed 'widespread' personal preferences for non-urban lifestyles. For example Breheny (1997) demonstrates that rural people show the highest levels of satisfaction with their area of residence (with 73% very satisfied), followed in order by rural resident/village centre (68%), suburban/residential (51%) and urban (36%)[42]. The same ordering emerges when satisfaction with housing is the criterion, though here the differences are a little less extreme (rural 69%, urban 46% very satisfied). Breheny quotes other work suggesting that people also prefer houses to flats. He concludes that the geographical areas and house types that compaction arguments promote are the very least popular, and that people would have to be 'coerced' into living in compact communities. Similarly Senior, Webster and Blank (2000)[43] report on their research in Cardiff and ask whether government policies seeking to encourage people to live in mixed land use and higher density neighbourhoods are realistic in the context of consumer preferences, i.e. people aspire to larger house types with gardens, in semi-rural locations, etc. - the antithesis of the urban renaissance vision (and interestingly their research is sponsored by the house building community).

In summary, the broad thesis appears to be that personality attributes are also associated with travel behaviour; potentially more so than land use characteristics. The key issues for this thesis, in terms of attitudes to travel, are:

[42] Hedges and Clemens (1994) also studied attitudes to housing for the DoE based on a survey of 3,285 households in 1992. People's satisfaction increased from big cities through smaller places to rural areas.
[43] This series of survey questions is similar to that used in Cardiff by Senior et al (2000). They cover satisfaction with area of residence, preferred home location, preferred type of home, preferred open space, preferred car parking arrangement.

- Are the findings of Kitamura et al (1997) also relevant to the UK context? Can attitudinal characteristics be related to travel behaviour in Surrey? Is there a relationship between attitude to the environment, public transport and time pressure etc. and travel behaviour?
- What is the impact of particular attitudinal factors on each of the components of travel behaviour: transport energy consumption, journey length, time and mode share?

EVIDENCE FROM SURREY: ATTITUDE TO TRAVEL AND TRAVEL BEHAVIOUR

To test for the attitudinal effect in Surrey, a similar survey[44] to the one used by Kitamura et al (1997) was included in the 2001 survey of new household occupiers. Table 5.15 shows the 39 questions included in the survey which were used to elicit views towards various aspects of life. Each was presented as a statement soliciting a response on an agree-disagree semantic scale.

Table 5.14: *Attitudinal Scoring System*

Respondent answer	Score
Strongly agree	2
Agree	1
Neither agree nor disagree	0
Disagree	-1
Strongly disagree	-2
Don't know	-

Table 5.15: *Attitudinal Variables*

Attitudinal Statement	Loading Factor	Mean Score	Standard Deviation
Factor 1: Pro-Environment			
▪ Environmental protection costs too much	-	-0.5	1.0
▪ Environmental protection is good for the Surrey economy	+	0.9	0.8
▪ Environmentalism hurts small businesses	-	-0.3	0.9
▪ People and jobs are more important than the environment	-	-0.3	1.0
▪ Strict pollution controls should be introduced and enforced	+	1.0	0.9
▪ Petrol prices should be raised to reduce congestion and air pollution	+	-0.7	1.2
▪ Vehicle emissions increase the need for health care	+	0.5	1.0
▪ Using taxes to pay for public transport is a good investment	+	0.8	1.0
▪ We should provide incentives to people who use electric vehicles	+	0.5	1.0
▪ Whoever causes environmental damage should repair the damage	+	1.0	0.9
Factor 1 Average		0.5	0.5
Factor 2: Pro-Public Transport			
▪ Buses and trains are pleasant to travel in	+	0.9	1.0
▪ I can read and do other things when I use public transport	+	0.5	1.0
▪ Public transport is unreliable	-	1.0	1.0
▪ Car sharing saves money	+	0.9	0.8
▪ I am not comfortable car sharing with strangers	-	0.9	1.0

[44] The survey statements for Surrey (2001) differ very slightly to Kitamura's earlier version which was carried out in San Francisco (1997). "*The rideshare car or van is often late*" was omitted from factor 2, as the question is not relevant in Surrey; there are very few ride-sharing schemes available in the county (in 2001). And the statement "*I would be willing to pay to park at work if it meant there would be less congestion*" was added to factor 7 as this a potential policy choice for the county.

▪ I like someone else to do the driving	+	0.4	1.1
▪ Too many people drive alone	+	0.7	0.9
▪ It costs more to use public transport than to drive a car	-	0.5	1.0
Factor 2 Average		-0.2	0.5
Factor 3: Suburbanite			
▪ I need to have space between me and my neighbours	+	1.1	0.9
▪ I would only live in a block of flats as a last resort	+	0.8	1.3
▪ It's important for children to have a large back garden for playing	+	0.9	0.9
▪ High density residential development should be encouraged	-	-0.8	1.0
Factor 3 Average		0.9	0.7
Factor 4: Car Mobility			
▪ Driving allows me to get more done	+	1.2	0.8
▪ Driving allows me more freedom	+	1.4	0.7
▪ I would rather drive an electric vehicle than give up driving	+	1.0	0.9
Factor 4 Average		1.2	0.6
Factor 5: Time Pressure			
▪ Getting stuck in traffic doesn't bother me too much	-	-0.5	1.1
▪ I would like to have more time for leisure	+	0.9	0.9
▪ I feel that I am wasting time when I have to wait	+	0.9	0.9
▪ Traffic congestion will take care of itself because people will adjust	-	-0.8	1.0
Factor 5 Average		0.8	0.6
Factor 6: Urban Villager			
▪ Having shops and services within walking distance is important	+	1.1	0.8
▪ Too much green belt and agricultural land is consumed by new housing	+	0.8	1.1
▪ I use public transport when I cannot afford to drive by car	+	0.7	1.0
Factor 6 Average		0.4	0.6
Factor 7: Traffic Demand Management			
▪ I would be willing to pay a toll to drive on an uncongested road	+	0.1	1.2
▪ I would be willing to pay to park at work if it meant there would be less congestion	+	-0.1	1.1
▪ More lanes should be set aside for buses and car sharing	+	0.0	1.2
▪ We need to build more roads to help reduce congestion	-	-0.1	1.2
Factor 7 Average		0.0	0.7
Factor 8: Workaholic			
▪ I like to spend most of my time working	+	-0.4	1.0
▪ When busy at work, I get more done by cutting back on personal time	+	0.2	1.0
▪ I would be willing to give up a day's pay to get a day off work	-	-0.2	1.1
Factor 8 Average		0.0	0.6

Data: Surrey New Occupiers Survey 2001.

Bearing in mind that semantic scales of this type tend to induce answers that are concentrated in the middle of the scale, i.e. few 'very satisfied' or 'very dissatisfied' answers, there is still an interesting range of results. In summary:

- Factor 1 Pro-environment: overall respondents are weakly pro-environment (0.5). The strongest opinions from respondents are that strict pollution controls should be introduced and enforced (1.0), whoever causes environmental damage should repair the damage (1.0), environmental protection is good for the economy (0.9), using taxes to pay for public transport is a good investment (0.8), but interestingly disagree that petrol prices should be raised to reduce congestion and air pollution (-0.7); the typical prisoner's dilemma.

- Factor 2 Pro-public transport: overall respondents are weakly anti-public transport (-0.2). The strongest opinions are that public transport is unreliable (1.0), buses and trains are pleasant to travel in (0.9), car sharing saves money (0.9), people are not comfortable car sharing with strangers (0.9) and too many people drive alone (0.7).

- Factor 3 Suburbanite: overall respondents are pro-suburbanite (0.9). The strongest opinions are that respondents need to have space between them and their neighbours (1.1), it is important that children have a large back garden for playing (0.9), people would only live in a block of flats as a last resort (0.8), and disgreement that high density residential development should be encouraged (-0.8).

- Factor 4 Car mobility: overall respondents are strong supporters of car mobility (1.2). The strongest opinions are that driving allows more freedom (1.4), driving allows respondents to get more done (1.2) and respondents would rather drive an electric vehicle than give up driving (1.0).

- Factor 5 Time pressure: overall respondents are time-pressured (0.8). The strongest opinions are that respondents would like more time for leisure (0.9), respondents feel that they are wasting time when they have to wait (0.9), and disagreement that traffic congestion will take car of itself because people will adjust (-0.8).

- Factor 6 Urban villager: overall respondents are weak supporters of urban village life (0.4). The strongest opinions are that having shops and services within walking distance is important (1.1) and too much green belt and agricultural land is consumed by housing (0.8).

- Factor 7 Traffic demand management (TDM): overall respondents are ambivalent to TDM (0). Average opinions on charging regimes, bus priority and car sharing and even building roads are negligible in their scores.

- Factor 8 Workaholic: overall respondents are ambivalent to work priorities (0). The strongest opinion is disagreement (not surprisingly perhaps) that people like to spend most of their time working (-0.4).

A further stage of analysis is to consider the attitudinal and travel behaviour relationship. Cross-tabulations prove to be very revealing. The following tables show differences in respondents' attitudes across the survey sample and average energy consumption, journey to work distance, journey to work time and mode share, for 2001 only. This analysis is a key progression from the Kitamura et al (1997) research, which considered number of person trips and transit/automobile mode share.

A strong caveat however: matching attitudes to travel to travel behaviour is not done without difficulties analytically. The cognitive dissonance effect[45] is important here - attitudes to travel and travel behaviour may not match, so careful interpreation of the results is required. Importantly

[45] Cognitive dissonance was first investigated by Festinger et al (1957), using a participant observation study of a cult which believed that the earth was going to be destroyed by a flood. The research considered what had happened to the cult members - particularly the committed ones who had given up their homes and jobs - when the flood did not happen. For further information see http: www.psychclassics.yorku.ca

though, again according to cognitive dissonance theory, there is a tendency for individuals to seek consistency among their cognitions (i.e., beliefs, opinions). When there is an inconsistency between attitudes or behaviours (dissonance), something must change to eliminate the dissonance. In the case of a discrepancy between attitudes and behaviour, it is most likely that the attitude will change to accommodate the behaviour (Festinger et al, 1957).

Table 5.16A: *Attitude to the Environment and Travel Behaviour*

Attitude: Pro-Environment (2001)	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
Strongly agree	50	46.5	28.8	43.7	55%
Agree	234	63.8	31.2	44.1	68%
Neither agree or disagree	16*	69.9	32.7	37.1	78%
Disagree	41	64.9	27.9	39.1	78%
Strongly disagree	2**	104.8	36.5	37.2	100%
Not stated	182	54.3	26.1	38.0	67%
Grand Total	525	59.4	29.0	41.4	68%

Shading Key

X: 5% > sample average

Y: 5% < sample average

Pro-environment attitudinal statements:

- Environmental protection costs too much (-ve)
- Environmental protection is good for the Surrey economy (+ve)
- Environmentalism hurts small businesses (-ve)
- People and jobs are more important than the environment (-ve)
- Strict pollution controls should be introduced and enforced (+ve)
- Petrol prices should be raised to reduce congestion and air pollution (+ve)
- Vehicle emissions increase the need for health care (+ve)
- Using taxes to pay for public transport is a good investment (+ve)
- We should provide incentives to people who use electric vehicles (+ve)
- Whoever causes environmental damage should repair the damage (+ve)

Data: Surrey New Household Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents).

The majority of respondents are pro-environment in their attitude (for example, stating that environmental protection is good for the economy); 82% of those who express an opinion agreeing with the pro-environment statements.

- As pro-environment attitudes increase energy consumption appears to decrease. The most fervent environmental supporters are associated with lower average energy consumption patterns (22% less than the sample average in 2001) and car mode shares (55%); than both the sample average and the strong antagonists (the latter consuming 76% more energy than the sample average).
- Correlation analysis supports these findings: a pro-environment attitude is strongly associated with reduced energy consumption.

Table 5.16B: *Attitude to the Environment and Travel Behaviour*

Socio-Economic Variable	Correlation	EC01	JD01
attenv	Kendall's Tau	-0.114**	-0.024
	Sig. (2-tailed)	0.006	0.571

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.42: *Attitude to the Environment and Energy Consumption*

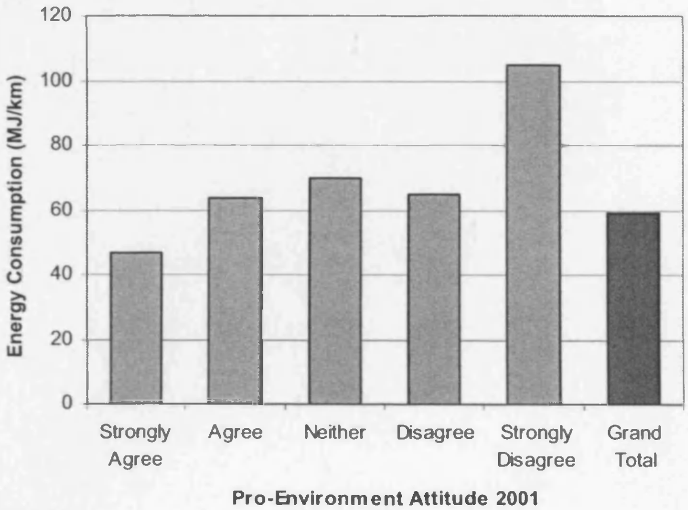


Figure 5.43: *Attitude to the Environment and Energy Consumption 2001*

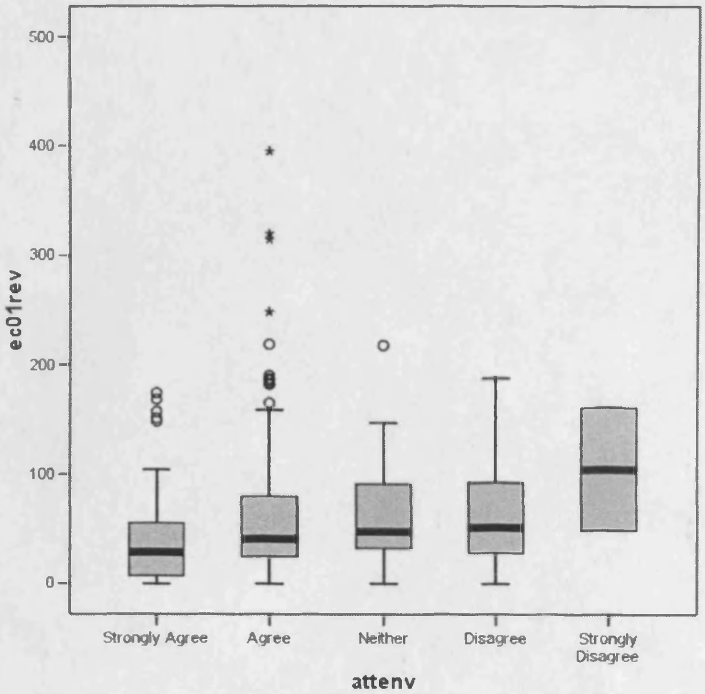


Table 5.17A: *Attitude to Public Transport and Travel Behaviour*

Attitude: Pro-Public Transport (2001)	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
Strongly agree	-	-	-	-	-
Agree	81	51.9	26.4	37.7	62%
Neither agree or disagree	34	72.7	39.0	52.6	65%
Disagree	212	63.7	31.0	43.8	70%
Strongly disagree	16*	66.1	29.2	41.8	82%
Not stated	182	54.3	26.1	38.0	67%
Grand Total	525	59.4	29.0	41.4	68%

Shading Key
X: 5% > sample average
Y: 5% < sample average

Pro-public transport attitudinal statements:

- Buses and trains are pleasant to travel in (+ve)
- I can read and do other things when I use public transport (+ve)
- Public transport is unreliable (-ve)
- Car sharing saves money (+ve)
- I am not comfortable car sharing with strangers (-ve)
- I like someone else to do the driving (+ve)
- Too many people drive alone (+ve)
- It costs more to use public transport than to drive a car (-ve)

Data: Surrey New Household Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents).

The majority of respondents are anti-public transport in their attitude (for example, believing that public transport is unreliable); 62% disagree with the pro-public transport statements.

A number of patterns are evident:

- No-one is strongly pro-public transport. The public transport supporters however are associated with lower average energy consumption patterns (13% less than the sample average), and shorter journey distance (9% less than average) and low car mode shares (at 62%). The strong antagonists are associated with higher energy consumption (11% higher than average).
- Correlation analysis supports these findings: a pro-public transport attitude is significantly associated with reduced energy consumption.

Table 5.17B: *Attitude to Public Transport and Travel Behaviour*

Socio-Economic Variable	Correlation	EC01	JD01
attpt	Kendall's Tau	-0.085*	-0.053
	Sig. (2-tailed)	0.039	0.213

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.44: *Attitude to Public Transport and Energy Consumption*

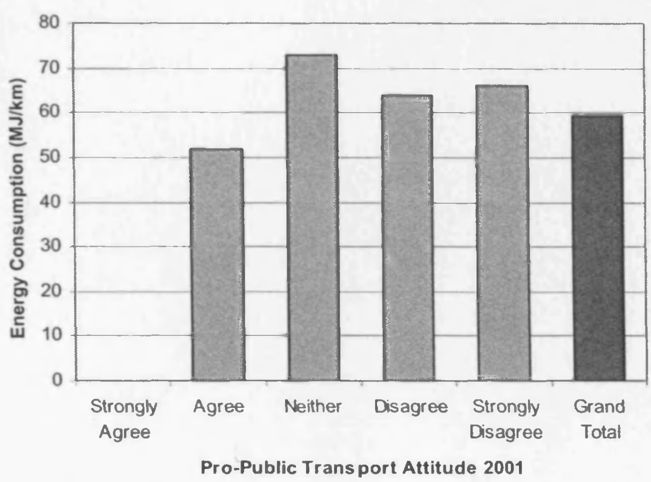


Figure 5.45: *Attitude to Public Transport and Energy Consumption 2001*

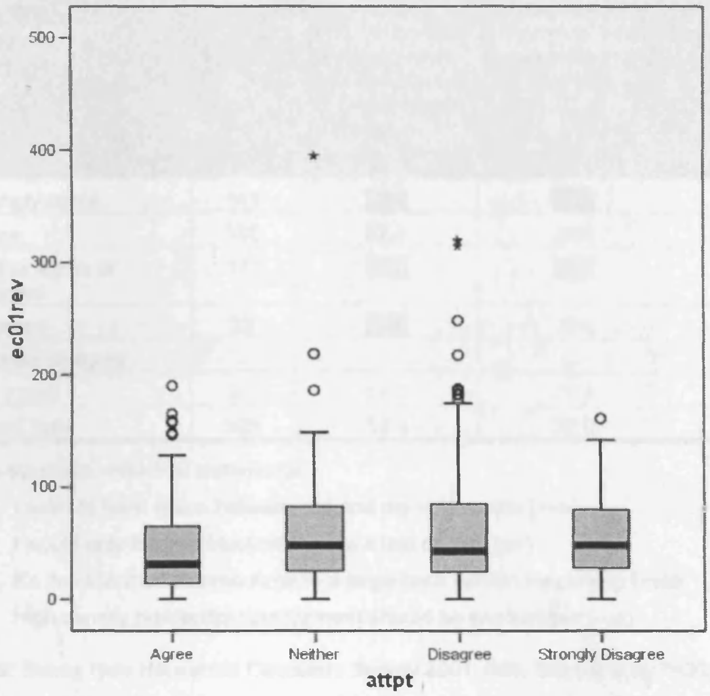


Table 5.18A: *Attitude to Suburban Residence and Travel Behaviour*

Attitude: Pro-Suburban Residence (2001)	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
Strongly agree	141	66.7	32.0	45.5	67%
Agree	160	57.7	29.9	42.5	68%
Neither agree or disagree	17*	54.0	25.7	37.6	65%
Disagree	25	69.1	30.4	37.3	74%
Strongly disagree	-	-	-	-	-
Not stated	182	54.3	26.1	38.0	67%
Grand Total	525	59.4	29.0	41.4	68%

Pro-suburban attitudinal statements:

- I need to have space between me and my neighbours (+ve)
- I would only live in a block of flats as a last resort (+ve)
- It's important for children to have a large back garden for playing (+ve)
- High density residential development should be encouraged (-ve)

Shading Key

X: 5% > sample average

Y: 5% < sample average

Data: Surrey New Household Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents).

The majority of respondents are pro-suburban in their household location preference (for example, they need to have space between them and their neighbours); 88% either agreeing or strongly agreeing with the pro-suburban statements (bear in mind this is Surrey, the most apposite suburban county in the UK for many).

- The relationship between suburban attitudes and travel behaviour is not clear. Correlation analysis supports these findings: there is no significant relationship between attitude to suburban residence and reduced energy consumption.

Table 5.18B: *Attitude to Suburban Residence and Travel Behaviour*

Socio-Economic Variable	Correlation	EC01	JD01
attres	Kendall's Tau	0.046	0.057
	Sig. (2-tailed)	0.262	0.178

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.46: *Attitude to Suburban Residence and Energy Consumption*

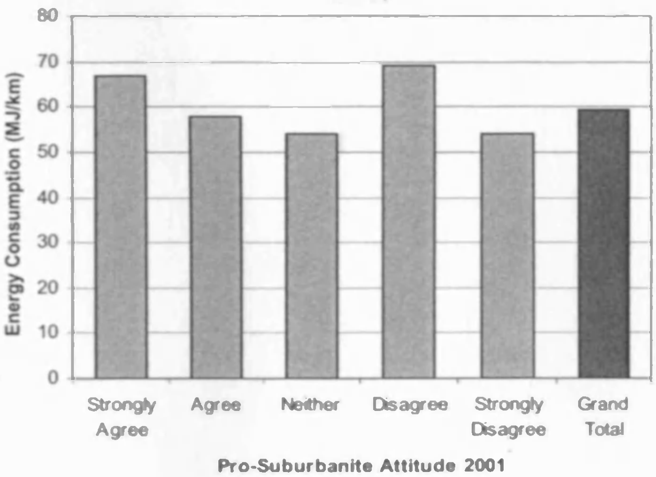


Figure 5.47: *Attitude to Suburban Residence and Energy Consumption 2001*

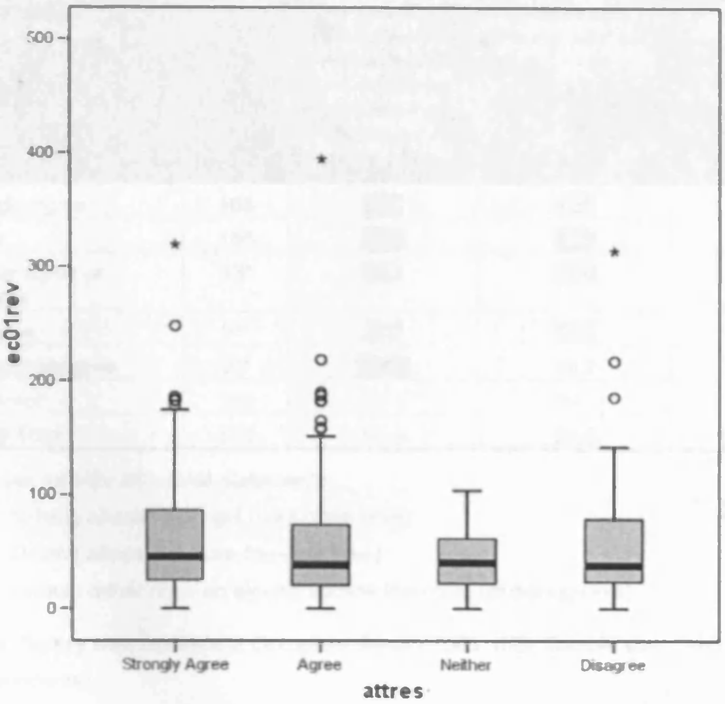


Table 5.19A: *Attitude to Car Mobility and Travel Behaviour*

Attitude: Pro-Car Mobility (2001)	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
Strongly agree	166	63.0	31.5	43.7	70%
Agree	156	62.4	30.6	43.3	66%
Neither agree or disagree	13*	44.1	25.0	41.7	65%
Disagree	5**	37.2	17.4	28.1	50%
Strongly disagree	2**	165.0	28.7	26.7	50%
Not stated	183	54.4	26.1	38.0	67%
Grand Total	525	59.4	29.0	41.4	68%

Shading Key

X: 5% > sample average

Y: 5% < sample average

Pro-car mobility attitudinal statements:

- Driving allows me to get more done (+ve)
- Driving allows me more freedom (+ve)
- I would rather drive an electric vehicle than give up driving (+ve)

Data: Surrey New Household Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents).

The majority of respondents are pro-car mobility in their attitude (for example, agreeing that driving allows them to get more done); 94% agree with the pro-car mobility statements.

A number of patterns are evident:

- The car mobility supporters are associated with higher than average energy consumption patterns (6% more than the sample average). Journey distance is longer and car mode share higher for the pro-car mobility cohorts. Sample sizes don't allow reliable conclusions to be drawn from the respondents who don't support car mobility

- Correlation analysis supports these findings: there is a significant weak relationship between attitude to car mobility and energy consumption.

Table 5.19B: *Attitude to Car Mobility and Travel Behaviour*

Socio-Economic Variable	Correlation	EC01	JD01
attmob	Kendall's Tau	0.089*	0.053
	Sig. (2-tailed)	0.035	0.218

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.48: *Attitude to Car Mobility and Energy Consumption*

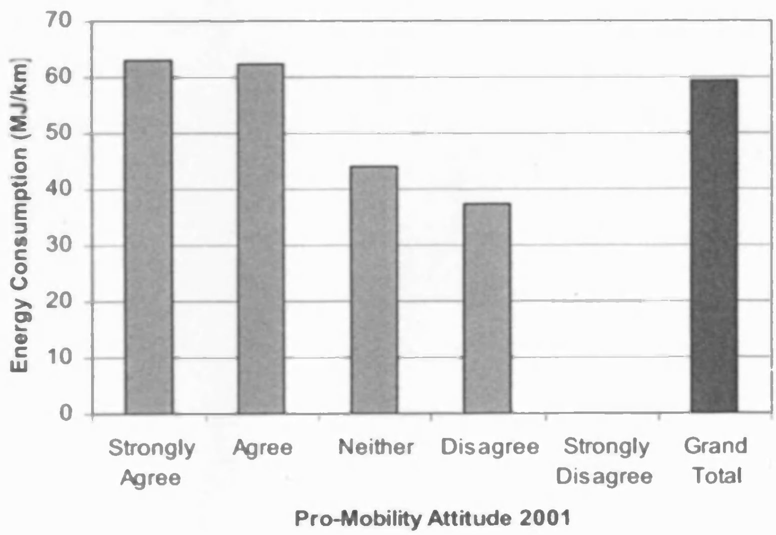


Figure 5.49: *Attitude to Car Mobility and Energy Consumption 2001*

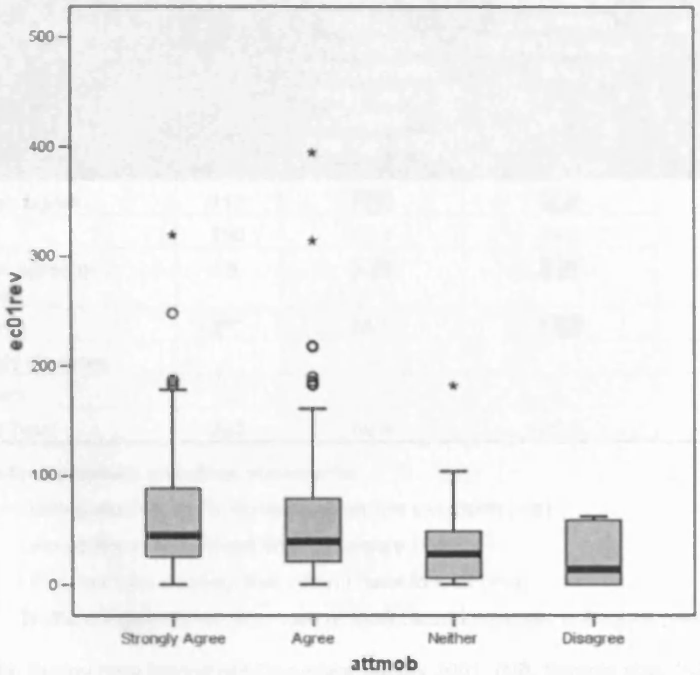


Table 5.20A: *Attitude to Time Pressure and Travel Behaviour*

Attitude: Pro-Time Pressure (2001)	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
Strongly agree	116	69.4	30.6	43.1	72%
Agree	190	60.1	29.3	41.2	69%
Neither agree or disagree	28	45.2	32.3	48.1	52%
Disagree	8**	58.2	53.7	72.7	45%
Strongly disagree	-	-	-	-	-
Not stated	183	54.4	26.1	38.0	67%
Grand Total	525	59.4	29.0	41.4	68%

Shading Key

X: 5% > sample average

Y: 5% < sample average

Pro-time pressure attitudinal statements:

- Getting stuck in traffic doesn't bother me too much (-ve)
- I would like to have more time for leisure (+ve)
- I feel that I am wasting time when I have to wait (+ve)
- Traffic congestion will take care of itself because people will adjust (-ve)

Data: Surrey New Household Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents).

The majority of respondents feel they are time pressured (for example, they would like to have more time for leisure); 89% agree or strongly agree with the time pressure statements.

A number of patterns are evident:

- Those who strongly agree they are time-pressured (for example, they would like to have more time for leisure) are associated with high average energy consumption patterns (17% more than the sample average) and high car mode shares (72%).

- Correlation analysis supports these findings: there is a significant weak relationship between attitude to time pressure and energy consumption.

Table 5.20B: *Attitude to Time Pressure and Travel Behaviour*

Socio-Economic Variable	Correlation	EC01	JD01
atttime	Kendall's Tau	0.084*	0.002
	Sig. (2-tailed)	0.043	0.957

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.50: *Attitude to Time Pressure and Energy Consumption*

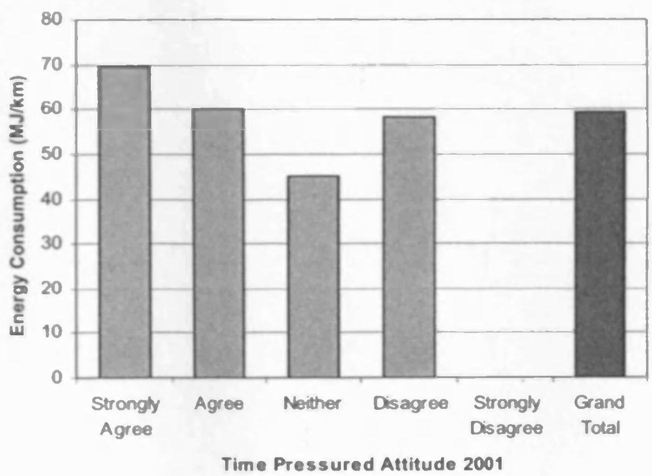


Figure 5.51: *Attitude to Time Pressure and Energy Consumption 2001*

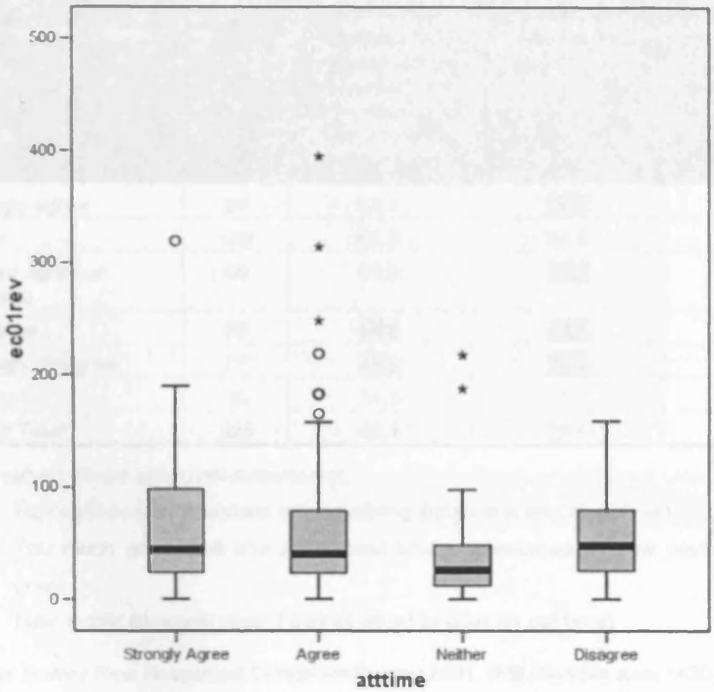


Table 5.21A: *Attitude to Urban Residence and Travel Behaviour*

Attitude: Pro-Urban Residence (2001)	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
Strongly agree	26	63.1	32.9	48.3	61%
Agree	189	61.6	28.8	40.0	67%
Neither agree or disagree	68	59.0	33.1	46.5	70%
Disagree	59	66.8	32.4	47.0	73%
Strongly disagree	1**	50.9	17.7	30.7	100%
Not stated	182	54.3	26.1	38.0	67%
Grand Total	525	59.4	29.0	41.4	68%

Pro-urban village attitudinal statements:

- Having shops and services within walking distance is important (+ve)
- Too much green belt and agricultural land is consumed by new housing (+ve)
- I use public transport when I cannot afford to drive by car (+ve)

Shading Key

X: 5% > sample average

Y: 5% < sample average

Data: Surrey New Household Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents).

The majority of respondents are positive about urban village lifestyles (for example, they like having shops and services within walking distance); 63% strongly agree or agree with the urban village statements.

A number of patterns are evident:

- There is appears to be a broad relationship with urban village attitude and travel behaviour in terms of mode share; the pro-urban village supporters are associated with low car mode shares (61% and 67%), whilst the antagonists have high car mode shares (73%).
- Correlation analysis supports these findings: there is a significant weak, and negative, relationship between attitude to time pressure and energy consumption.

Table 5.21B: *Attitude to Urban Residence and Travel Behaviour*

Socio-Economic Variable	Correlation	EC01	JD01
attuv	Kendall's Tau	-0.084*	-0.061
	Sig. (2-tailed)	0.038	0.141

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.52: *Attitude to Urban Residence and Energy Consumption*

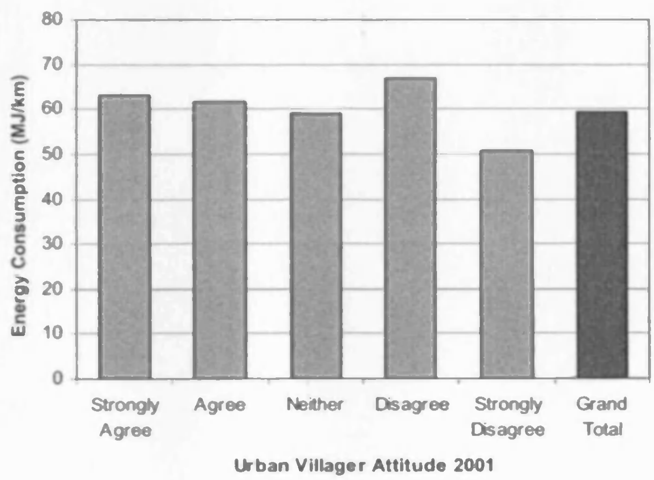


Figure 5.53: *Attitude to Urban Residence and Energy Consumption 2001*

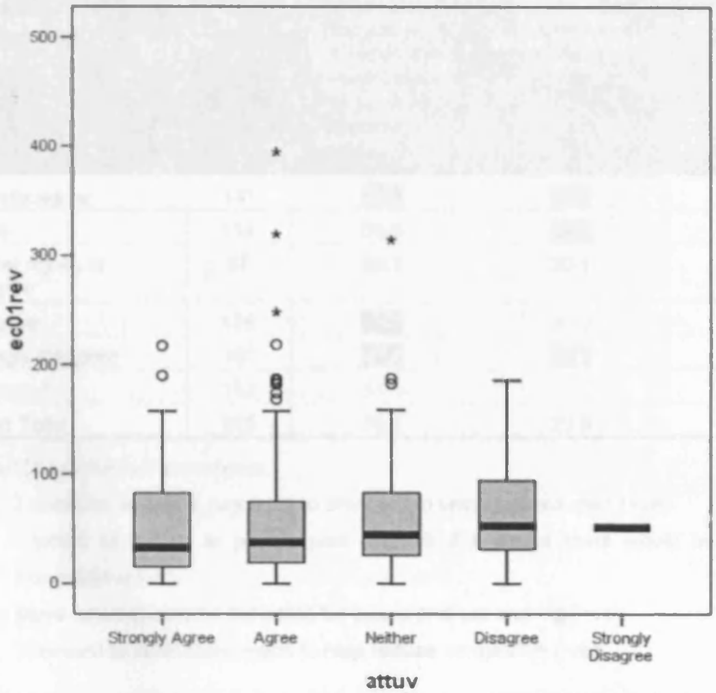


Table 5.22A: *Attitude to Traffic Demand Management and Travel Behaviour*

Attitude: Pro-TDM (2001)	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
Strongly agree	14*	51.4	23.5	33.9	71%
Agree	114	56.9	31.9	47.5	61%
Neither agree or disagree	57	58.1	30.1	41.5	69%
Disagree	138	66.7	30.3	41.4	71%
Strongly disagree	19*	77.7	31.6	41.1	85%
Not stated	183	54.4	26.1	38.0	67%
Grand Total	525	59.4	29.0	41.4	68%

Pro-TDM attitudinal statements:

- I would be willing to pay a toll to drive on an uncongested road (+ve)
- I would be willing to pay to park at work if it meant there would be less congestion (+ve)
- More lanes should be set aside for buses and car sharing (+ve)
- We need to build more roads to help reduce congestion (-ve)

Shading Key

X: 5% > sample average

Y: 5% < sample average

Data Data: Surrey New Household Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents).

Opinion is split as to traffic demand management (for example, whether respondents would be willing to pay tolls to drive on an uncongested road); of those who replied 33% agree and 40% disagree with the TDM statements.

- The relationship between TDM attitude and travel behaviour appears clear; those who most strongly agree in TDM have the least energy intensive travel patterns. For example, those who strongly agree consume 13% less than average, those who strongly disagree consume 30% more than average.

- Correlation analysis supports these findings: there is a significant weak, and negative, relationship between attitude to TDM and energy consumption.

Table 5.22B: *Attitude to TDM and Travel Behaviour*

Socio-Economic Variable	Correlation	EC01	JD01
attdm	Kendall's Tau	-0.087*	-0.013
	Sig. (2-tailed)	0.030	0.757

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.54: *Attitude to TDM and Energy Consumption 1998*

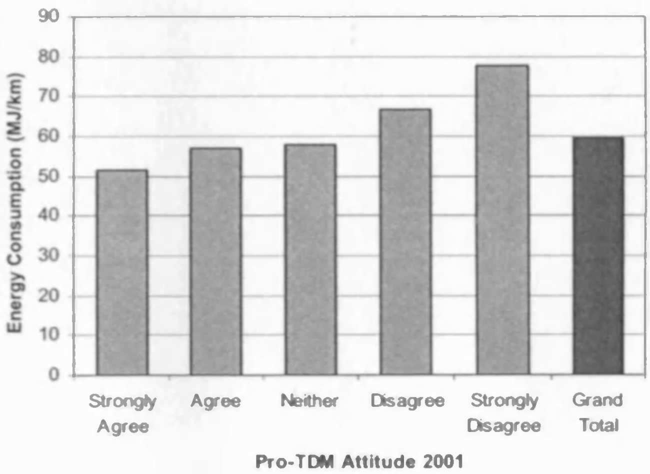


Figure 5.55: *Attitude to TDM and Energy Consumption 2001*

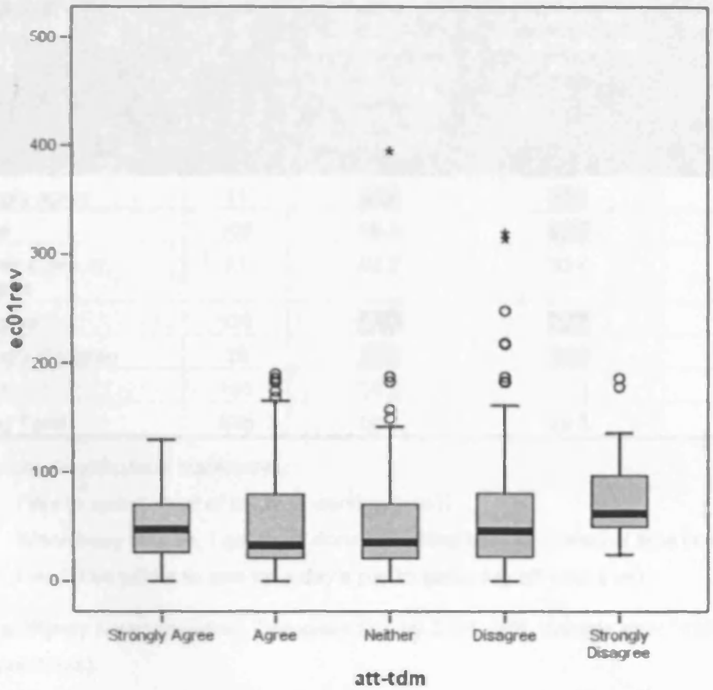


Table 5.23A: *Attitude to Working Time and Travel Behaviour*

Attitude: Workaholic (2001)	Count	Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)	Average of Journey to Work Distance, Km	Average of Journey to Work Time, Mins	% Car Driver
Strongly agree	11	55.4	21.5	25.5	69%
Agree	108	59.3	30.8	44.6	66%
Neither agree or disagree	71	62.2	30.4	44.7	68%
Disagree	137	64.2	32.4	44.1	68%
Strongly disagree	13	54.7	17.1	25.8	73%
Not stated	185	55.2	26.3	38.0	67%
Grand Total	525	59.4	29.0	41.4	68%

Workaholic attitudinal statements:

- I like to spend most of my time working (+ve)
- When busy at work, I get more done by cutting back on personal time (+ve)
- I would be willing to give up a day's pay to get a day off work (-ve)

Shading Key

X: 5% > sample average

Y: 5% < sample average

Data: Surrey New Household Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents).

Again, opinion is split as to workaholic attitude (for example, when respondents are busy at work, they get more done by cutting back on personal time); 31% agree and 40% disagree with the workaholic statements.

- The relationship between workaholic attitude and travel behaviour is not clear; although those that strongly disagree (for example, don't like to spend most of their time working) are the least energy consuming in their commuting travel behaviour (consuming 7% less energy than the sample average).
- Correlation analysis supports these findings: there is no significant relationship between attitude to working time and energy consumption.

Table 5.23B: *Attitude to Working TIme and Travel Behaviour*

Socio-Economic Variable	Correlation	EC01	JD01
attwork	Kendall's Tau	-0.007	0.004
	Sig. (2-tailed)	0.862	0.922

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Figure 5.56: *Attitude to Working Time and Energy Consumption*

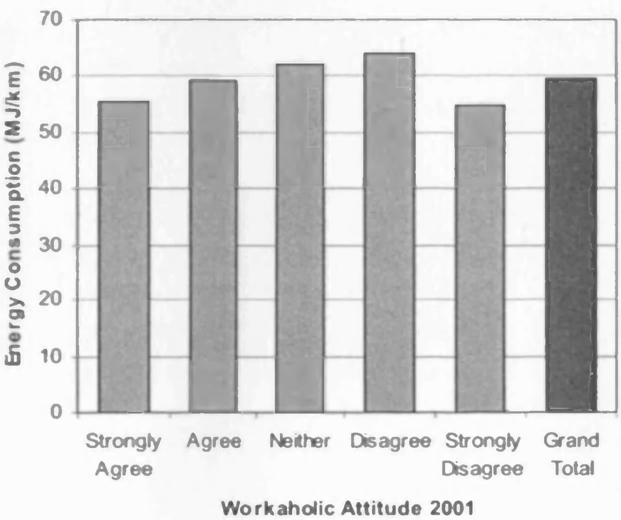
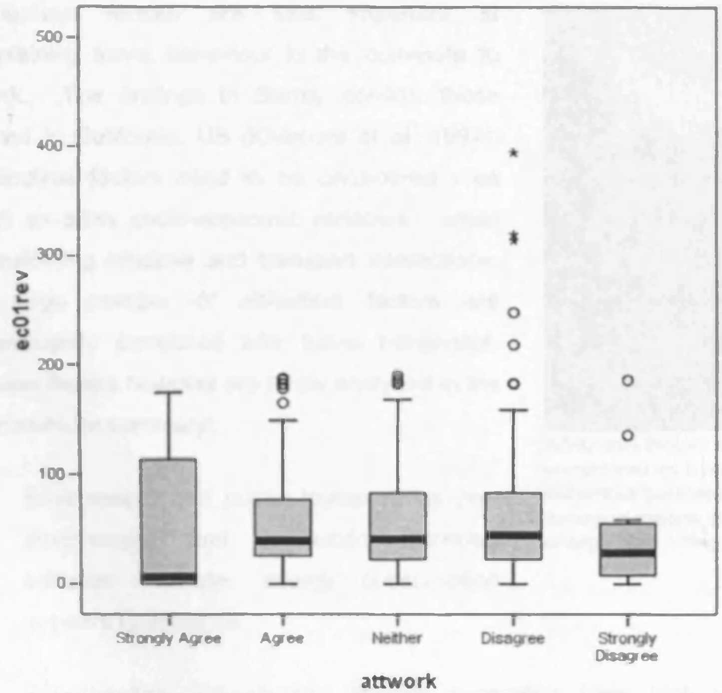


Figure 5.57: *Attitude to Working Time and Energy Consumption 2001*



5.2.2 Attitudes to Travel: Conclusions

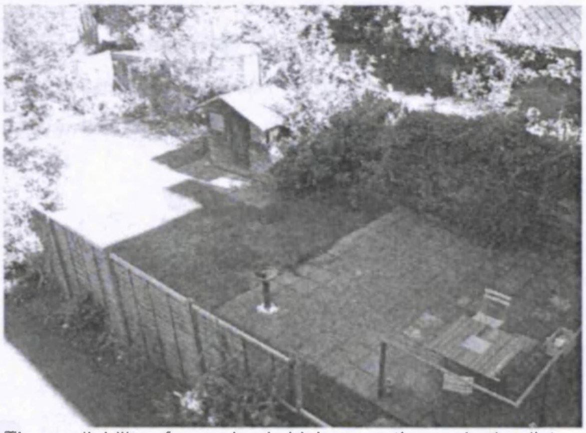
Attitudinal factors are thus important in explaining travel behaviour in the commute to work. The findings in Surrey confirm those found in California, US (Kitamura et al, 1997): attitudinal factors need to be considered - as well as other socio-economic variables - when considering landuse and transport interactions. A large number of attitudinal factors are significantly correlated with travel behjaviour. These factors however are rarely analysed in the literature. In summary:

Attitudinal factors are important, and need to be considered as a contributory factor in explaining travel behaviour patterns. Being pro-environment or pro-public transport means an individual is more likely to be less energy consuming in their travel behaviour.

- Environment and public transport: as pro-environment and pro-public transport attitudes increase, energy consumption appears to decrease.
- Suburbanites: pro-suburban lifestyle supporters have high average energy consumption patterns.
- Car mobility: car mobility supporters are associated with high energy consumption patterns.
- Time pressure: those who aren't time pressured are associated with high energy consumption patterns.
- Urban villagers: pro-urban village supporters are associated with low average energy consumption patterns.
- Traffic demand management: those who most strongly agree with TDM measures are associated with lower energy consumption patterns.
- Workaholics: those who don't like to spend most of their time working are associated with the least energy consumption patterns in their commutes to work.

The policy implications of these findings are great. As we delve deeper and deeper into our understanding of the data, we uncover more and more nuances. Different segments of the population - whether by attitude, or socio-economic characteristic, or type of area in terms of urban form - travel in different ways and *derive* their travel in different ways. The rationale for their resulting travel behaviour differs. Hence it should not be surprising that the 'planning for all' approach is sometimes off the mark - in particular it should not be unexpected that we fail to reduce travel and energy consumption by targeting the population as a consistent unity. The case for a greater differentiation in policy approach at the regional, sub-regional and local level - in integrating land use and transport planning (and indeed in wider urban planning fields) - is thus very strong, if not overwhelming.

5.2.3 Attitudes to Home and Home Location



The availability of a garden is high up on the aspiration list for Surrey residents, typically alongside large detached houses and semi-rural locations.

A further dimension to the attitudinal debate is the level of satisfaction individuals show with their homes and places of residence, and their desires for future location. In attempting to unravel these issues, the 2001 respondents were also asked a number of questions concerning satisfaction with their home and home location. This develops the thinking of Breheny et al (1998) and Senior, Webster and Blank (2000)[46], as discussed earlier, who query the practical potential for/utility of land use planning in reducing travel, particularly the use of the urban renaissance approach outside the key urban areas. We will see that there is almost universal support amongst the survey respondents for a particular style of living: one that involves a detached house with a garden, a garage and a location in a rural or suburban village centre.

Table 5.24: *Satisfaction with Area of Residence*

Satisfaction Rating	Count 2001	% of Total	Average of Energy Consumption (MJ/jtw)	Average of Journey to Work Distance (Km)	Average of Journey to Work Time (Mins)	% Car Driver
Very satisfied	147	43%	67.1	31.2	43.7	66%
Satisfied	172	50%	58.2	29.8	41.8	70%
Dissatisfied	16*	5%	78.1	42.3	56.9	56%
Very dissatisfied	9**	3%	39.6	18.3	31.9	73%
Not stated	181	-	53.4	25.8	38.0	67%
Grand Total	525	100%	59.4	29.0	41.4	68%

Data: Surrey New Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

Y: 5% < sample average

[46] This series of survey questions is similar to that used by Senior et al (2000). They cover satisfaction with area of residence, preferred home location, preferred type of home, preferred open space, preferred car parking arrangement.

Most new household occupiers are satisfied or very satisfied with their area of residence (93% of respondents):

- The highest energy consumers are those who are dissatisfied with their area of residence (consuming 31% more than the sample average); the high consumption being due to lengthy commute distances (an average of 42km, 46% higher than the sample average) rather than a high car mode share.

Figure 5.58: *Satisfaction with Area of Residence*

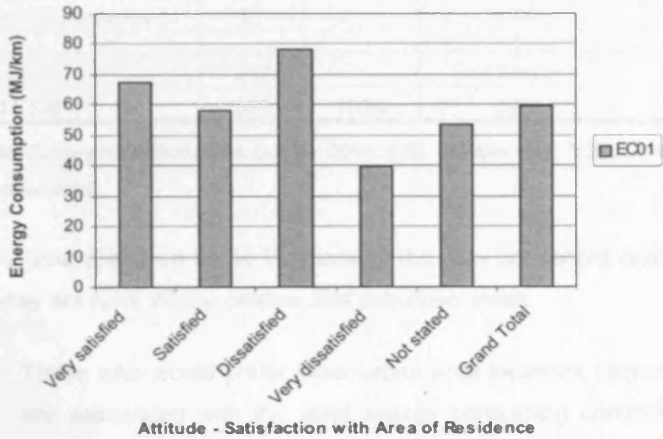


Table 5.25: *Preferred Home Location*

Location Type	Count 2001	% of Total	Average of Energy Consumption (MJ/jtw)	Average of Journey to Work Distance (Km)	Average of Journey to Work Time (Mins)	% Car Driver
Rural village centre	171	53%	62.3	28.4	40.9	71%
Suburban area	86	27%	59.6	29.1	41.0	68%
Remote rural area	34	11%	67.6	37.8	50.1	63%
Major suburban centre	13*	4%	102.5	56.3	72.7	44%
Other (inner urban)	19*	6%	58.4	27.1	40.4	70%
City centre	9**	-	28.9	24.3	46.0	64%
Inner urban area	8**	-	95.0	33.0	37.9	70%
Redeveloped dockland area	2**	-	45.1	15.7	24.9	100%
Not stated	202	-	53.8	25.8	37.8	
Grand Total	525	100%	59.4	29.0	41.4	68%

Data: Surrey New Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key
X: 5% > sample average
Y: 5% < sample average

The clear preferred home locations of the new household occupiers in Surrey are rural village centres and suburban areas.

- Those who would prefer inner urban area locations (including city centre or dockland homes) are associated with the least energy consuming commuting behaviours, suggesting that a certain type of people are attracted to these locations. The environment by itself does not determine travel behaviour; attitude appears important.

Figure 5.59: *Preferred Home Location*

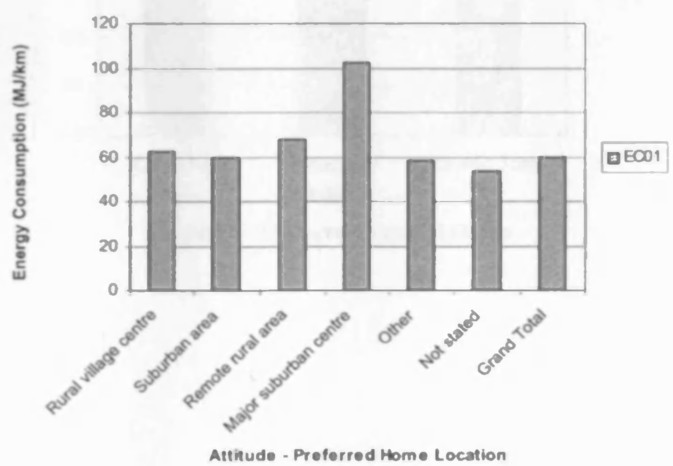


Table 5.26: *Preferred Type of Home*

Home Type	Count 2001	% of Total	Average of Energy Consumption (MJ/jtw)	Average of Journey to Work Distance (Km)	Average of Journey to Work Time (Mins)	% Car Driver
Detached house	292	87%	63.3	31.1	44.2	68%
Detached bungalow	30	9%	47.4	26.9	37.3	63%
Other	14	4%	75.9	24.7	26.3	76%
Purpose-built flat	8**	-	73.6	22.4	22.8	70%
Terraced house	4**	-	91.4	31.8	35.8	80%
Semi-detached house	2**	-	53.8	18.7	20.1	100%
Not stated	189	-	53.7	25.9	38.0	69%
Grand Total	525	100%	59.4	29.0	41.4	68%

Data: Surrey New Occupiers Survey 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key
X: 5% > sample average
Y: 5% < sample average

The vast majority of respondents would prefer a detached house as their home; and these new household occupiers are associated with slightly more energy consuming journey to work travel behaviour than the sample average.

Figure 5.60: *Preferred Type of Home*

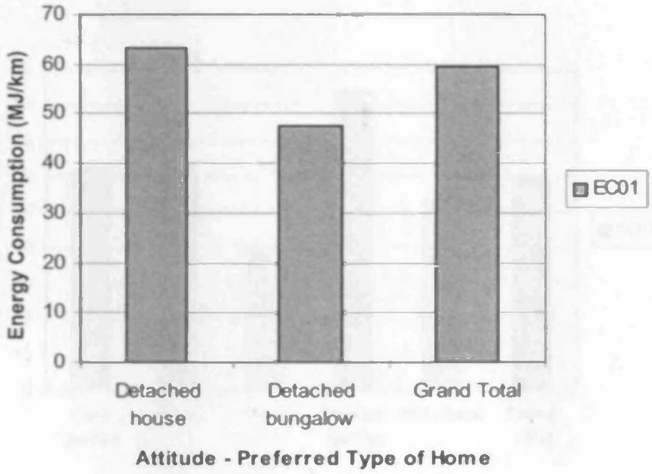


Table 5.28: *Preferred Car Parking*

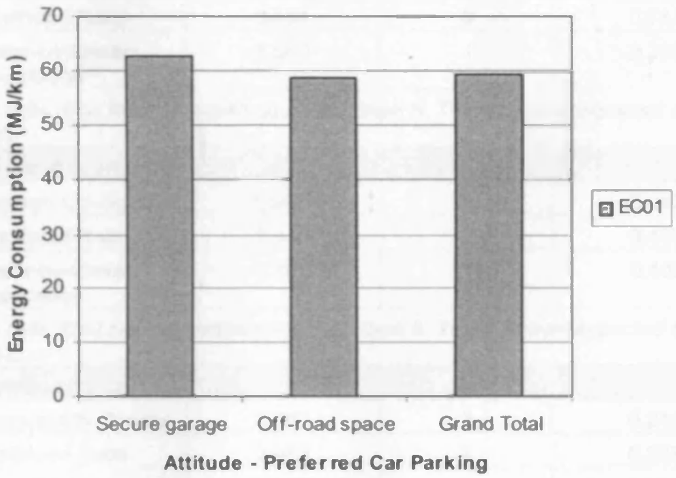
Car Park Type	Count 2001	% of Total	Average of Energy Consumption (MJ/jtw)	Average of Journey to Work Distance (Km)	Average of Journey to Work Time (Mins)	% Car Driver
Parking in secure garage	305	88%	62.9	31.1	43.9	69%
Parking in off-road parking space	40	12%	58.8	27.4	37.1	64%
Not stated	180	-	53.4	25.8	38.0	69%
Grand Total	525	100%	59.4	29.0	41.4	68%

Data: Surrey New Occupiers Survey 2001.

Shading Key
X: 5% > sample average
Y: 5% < sample average

The vast majority of respondents prefer their own parking in a secure garage; and again it is these very new household occupiers are associated with slightly more energy consuming journey to work travel behaviour than the sample average. Those who prefer parking in an off-road parking space are associated with reduced energy consuming journey to work travel behaviour.

Figure 5.62: *Preferred Car Parking*



In terms of strength of relationships between attitudes to home and home location, chi-square analysis however suggests that there are no significant relationships here.

Table 5.28B: *Attitudes to Home and Home Location and Travel Behaviour*

Chi-Square Test	Value	df	Asymp. Sig. (2-sided)
Satisfaction with area of residence-EC01			
Pearson Chi-Square	3.515	4	0.476
Likelihood Ratio	3.233	4	0.520
Linear-by-Linear Association	0.000	1	0.998
[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 6.10.			
Preferred home location-EC01			
Pearson Chi-Square	0.202[a]	4	0.995
Likelihood Ratio	0.198	4	0.995
Linear-by-Linear Association	0.018	1	0.892
[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 5.22.			
Preferred type of home-EC01			
Pearson Chi-Square	2.753[a]	6	0.839
Likelihood Ratio	3.481	6	0.747
Linear-by-Linear Association	1.580	1	0.209
[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 5.05.			
Preferred open space-EC01			
Pearson Chi-Square	1.544[a]	2	0.462
Likelihood Ratio	1.470	2	0.479
Linear-by-Linear Association	0.701	1	0.403
[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 9.82.			
Preferred car parking-EC01			
Pearson Chi-Square	3.067	2	0.216
Likelihood Ratio	2.962	2	0.227
Linear-by-Linear Association	0.120	1	0.729
[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 9.82.			

N = 525 in 2001

***Correlation is significant at the 0.01 level (2-tailed)*

**Correlation is significant at the 0.05 level (2-tailed)*

5.2.4 Reason for Moving/Choosing New Home

As a complement to the individual and household characteristic survey data, respondents were also asked their reasons for moving from their previous home and reasons for choosing their new home location. The results are shown in the following tables and diagrams.

Table 5.29A: *Reason for Moving from Previous Home and Travel Behaviour*

Reason For Moving From Previous Home	Count		Average of Energy Consumption (MJ/jtw)		Average of Journey to Work Distance (Km)		Average of Journey to Work Time (Mins)		% Car Driver	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Bigger House	524	178	62.3	[illegible]	32.0	30.1	45.3	43.3	73%	71%
Change in Workplace	273	70	57.4	56.5	29.7	32.1	41.0	44.7	71%	54%
Good Environment	179	56	59.7	[illegible]	29.5	28.4	41.5	39.2	69%	67%
Buy/Rent First Home	179	64	56.2	60.7	29.5	30.7	42.9	41.1	68%	72%
Smaller House	88	22	52.0	46.8	22.4	26.5	30.3	37.5	80%	75%
Marriage	81	19*	66.4	51.5	31.1	33.2	40.9	51.5	76%	64%
Relationship Breakdown	63	24	58.0	55.2	26.8	18.2	38.5	26.9	84%	88%
Existing Workplace	59	18*	69.6	51.4	29.4	22.7	37.7	30.5	90%	62%
Close to Family/Friends	36	12*	94.4	53.5	43.8	34.4	54.2	45.7	68%	71%
Good Schools	17*	7**	59.9	63.8	32.7	29.5	52.2	52.5	59%	57%
Other	154	55	58.0	53.5	27.8	25.2	38.2	38.7	69%	70%
Retirement	13*	3**	44.9	22.6	29.4	7.9	42.9	16.5	71%	100%
Price of New Home	11*	6**	38.7	77.2	39.2	35.7	56.3	53.4	69%	71%
Road Network	7**	-	148.4	-	64.4	-	59.2	-	88%	-
Shops/Leisure	3**	-	15.1	-	14.4	-	18.6	-	0%	-
Public Transport	-	-	-	-	-	-	-	-	-	-
Other reason	120	46	50.4	51.3	24.8	24.9	35.3	38.2	69%	68%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents).

Shading Key

X: 5% > sample average

Y: 5% < sample average

The most frequent reasons for respondents moving are to a bigger house (32% in 1998 and 34% in 2001), a change in workplace (17% in 1998 and 13% in 2001), to buy/rent a first home (11% in 1998 and 12% in 2001), a good environment (11% in 1998 and 11% in 2001). Transport is very much a lower order factor in decision-making; for example the road network scores very infrequently and public transport doesn't feature at all.

- The reasons for moving and associated travel behaviour follow some logic; the higher energy consumers are as follows: those that deem the road network to be important (146% higher than the sample average in 1998), or to be close to family/friends (57% in 1998), or an existing workplace (16%). We can see that reasons considered as important in the move from the previous home often lead to longer journey to work distances, but appear to be traded-off in the decision-making process as an acceptable price to pay for, for example, being close to family or friends, or having an affordable home, etc.

Correlation analysis supports these findings: there is a weak significant relationship between reason for moving and energy consumption.

Table 5.29B: *Reasons for Moving and Travel Behaviour*

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
Reasonmov-EC98			
Pearson Chi-Square	18.71	8	0.017*
Reasonmov-EC01			
Pearson Chi-Square	23.41	20	0.269

***Chi-square is significant at the 0.01 level.*

**Chi-square is significant at the 0.05 level.*

Figure 5.63: *Reason for Moving and Energy Consumption*

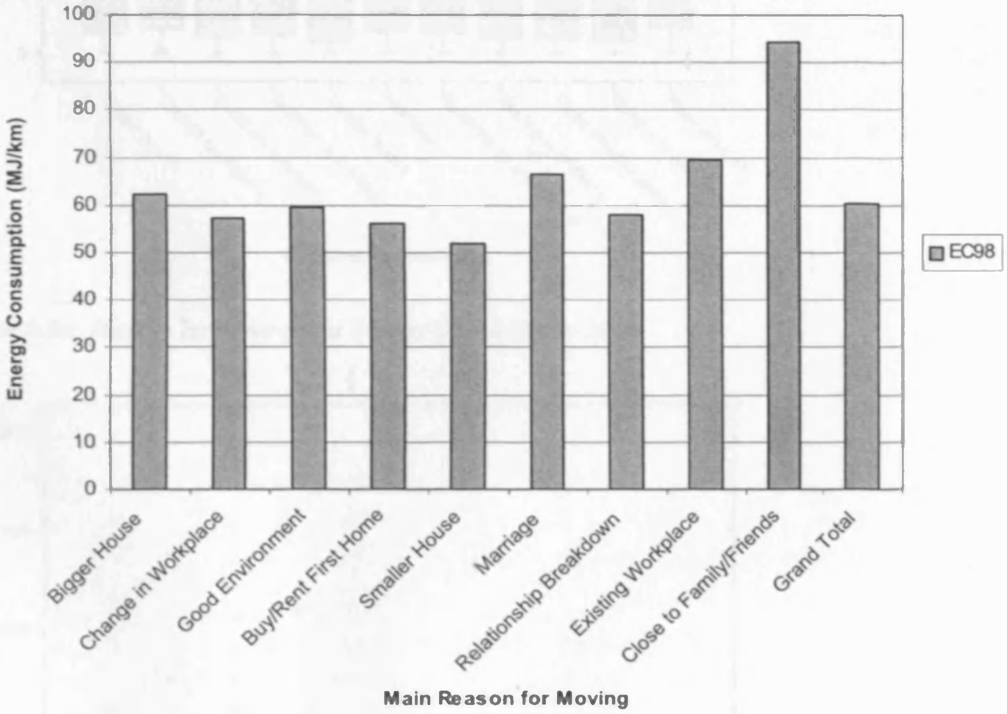


Figure 5.64: *Reason for Moving and Energy Consumption 1998*

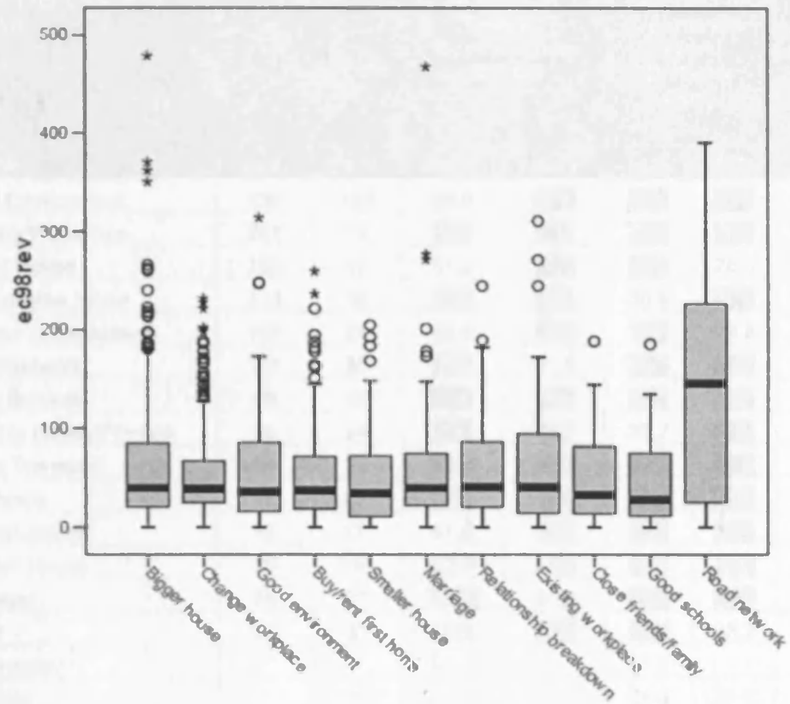


Figure 5.65: *Reason for Moving and Energy Consumption 2001*

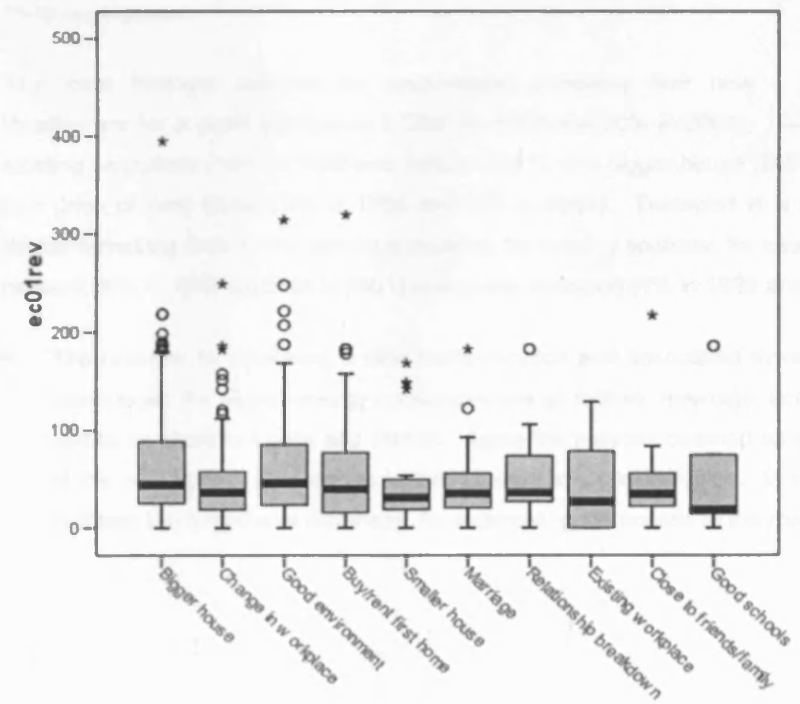


Table 5.30A: *Reason for Choosing Location and Travel Behaviour*

Reason for Choosing Location	Count		Average of Energy Consumption (MJ/jtw)		Average of Journey to Work Distance (Km)		Average of Journey to Work Time (Mins)		% Car Driver	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Good Environment	438	158	59.8	63.4	31.9	30.7	46.7	45.5	71%	68%
Existing Workplace	241	74	53.2	54.2	25.9	24.7	36.7	34.6	75%	73%
Bigger House	153	47	61.2	65.0	28.2	28.5	38.2	38.3	74%	78%
Price of New Home	113	32	52.6	66.0	30.5	35.2	41.7	47.0	70%	74%
Change in Workplace	107	27	63.0	55.9	27.5	29.8	36.4	40.3	74%	50%
Road Network	101	35	80.3	61.8	36.9	21.3	45.0	28.0	80%	67%
Good Schools	88	18*	63.7	71.5	28.4	27.4	40.6	36.3	73%	67%
Close to Family/Friends	86	24	67.2	45.7	30.7	22.1	41.0	31.0	71%	73%
Public Transport	64	22	44.1	77.0	47.8	50.1	74.2	77.9	36%	43%
First home	48	19*	57.1	35.0	24.4	20.4	31.4	29.7	78%	64%
Shops/Leisure	42	12*	57.8	38.7	24.4	25.5	37.3	42.7	77%	64%
Smaller House	39	18*	62.9	51.5	26.6	26.9	32.8	35.9	80%	79%
Marriage	26	8**	110.4	60.5	42.1	45.7	47.5	65.8	64%	44%
Other	98	31	53.0	64.0	24.8	28.2	34.4	39.7	75%	66%
Retirement	9**	-**	26.1	-	13.2	-	23.5	-	78%	-
Divorce	7**	5**	72.2	28.9	32.3	26.8	41.0	43.5	78%	60%
Other reason	55	20	56.6	57.8	26.9	25.8	35.8	36.3	73%	71%
Not stated	36	6**	49.5	62.2	20.0	37.6	31.0	48.1	77%	56%
Grand Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents).

Shading Key

X: 5% > sample average

Y: 5% < sample average

The most frequent reasons for respondents choosing their new location are for a good environment (26% in 1998 and 30% in 2001), existing workplace (15% in 1998 and 14% in 2001), to a bigger house (9% in 1998 and 9% in 2001) and price of new home (7% in 1998 and 6% in 2001). Transport is a more important factor in decision-making than in the previous reasons for moving analysis; for example access to the road network (6% in 1998 and 7% in 2001) and public transport (4% in 1998 and 4% in 2001).

- The reasons for choosing a new home location and associated travel behaviour again follow some logic; the higher energy consumers are as follows: marriage, access to the road network, and to be close to family and friends. Again the reasons deemed as important in the choosing of the new home often lead to longer journey to work distances. In some cases they actually facilitate the long travel distances, for example, good access to the road network.

Correlation analysis show any relationships are very weak - there is no significant relationship between reason for choosing a new home location and energy consumption.

Table 5.30B: *Reasons for Choosing New Location and Travel Behaviour*

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
Reasonch-EC98			
Pearson Chi-Square	4.98 "	8	0.759
Reasonch-EC01			
Pearson Chi-Square	1.97 °	8	0.982

***Chi-square is significant at the 0.01 level.*

**Chi-square is significant at the 0.05 level.*

Figure 5.66: *Reason for Choosing New Location and Energy Consumption*

Figure 5.67: *Reason for Choosing New Location and Energy Consumption 1998*

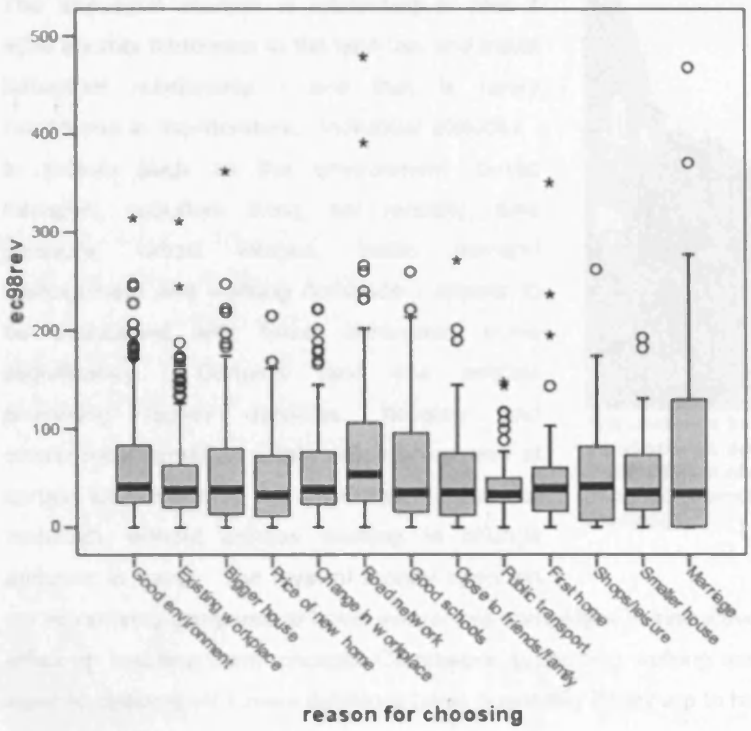
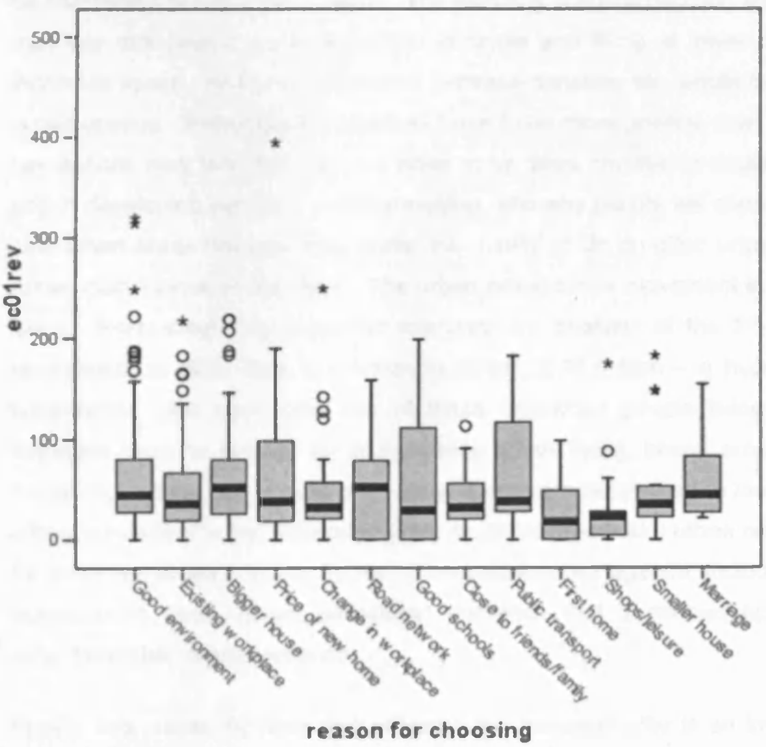


Figure 5.68: *Reason for Choosing New Location and Energy Consumption 2001*



Attitude and Travel Behaviour: Summary Thoughts

The challenge for new development is to create attractive urban spaces; and this means a move away from the standard level of quality (Whiteley Village: an interestingly designed community, housing elderly residents, in Elmbridge)

The attitudinal analysis is interesting in that it adds another dimension to the land use and travel behaviour relationship - one that is rarely considered in the literature. Individual attitudes - to factors such as the environment, public transport, suburban living, car mobility, time pressure, urban villages, traffic demand management and working demands - appear to be associated with travel behaviour, some siignificantly. Certainly land use policies promoting higher densities, housing and employment provision within urban areas and at certain locations may not alter travel behaviour materially without policies seeking to change attitudes to travel. The level of money spent on car advertising compared to travel awareness campaigns is instructive; and is very likely to have an effect on resulting travel choices. Campaigns supporting walking and cycling and public transport need to compete on a more equitable basis financially if they are to have an impact.

The second level of analysis covering individual preferences - as to detached house, private garden, own garage, etc. and reasons for moving from present location/choosing new location - can be interpreted in a number of ways. The planning sceptics (Gordon and Richardson, Breheny et al) may say that people prefer suburban lifestyles and living at lower densities which ensure more individual space. Hence any moves to increase densities etc. would be counter to the strong tide of public opinion. Policy-makers however have to be more positive than this. Although current public perceptions may lean this way, we need to be more creative in designing attractive urban spaces and in developing our skills in place-making, whereby people will choose to live in redeveloped and new urban areas because they prefer the quality of life on offer: urban areas as 'places of choice' rather than 'places of rejection'. The urban renaissance movement in the UK is based around this issue. Interestingly, demographic forecasts are positive: of the 3.5 million forecast increase in households to 2011 (and 4.4 million to 2016), 2.76 million – a huge 79% - will be one person households, with more than half of these unmarried people living alone. The opportunity is therefore there to provide for high-density urban living, based around a much-improved public transport, walking and cycling offer, with residents located close to local shops and amenities. The difficulty however is translating the (very much urban-centric) urban renaissance into a distinct form for suburban areas such as Surrey. The sustainability agenda, including a need to reduce energy consumption (and carbon emissions) demands that a revised approach is taken within our suburban/urban fringe locations.

Finally, the results illustrate that although the transport offer is an important part of the decision-making process involved in choosing to move or choosing a new home location, it is very much a lower order factor. A good environment, the type of residence and price of residence are all more important factors influencing the choice of location. Having said that, transport still plays an important role in the choice of a new home location. The conclusion made from the analysis is that the attitudinal/behavioural/sociological side of urban and transport planning - which is almost universally ignored in the literature - is very important. There is an urgent need for further research here; multi-dimensional thinking is again critical if we are to better understand how to design for less travel.

5.2.5 Relative Levels of Mobility

There is also very little research evidence available that considers the effect of relative mobility on travel behaviour. Relative mobility can be viewed as a type of 'peer effect', i.e. the average mobility level for a surrounding area might be associated with individual travel behaviour. The argument is that a mobile area will attract mobile individuals - for example an area with good access to the strategic transport network. As we have seen, accessibility to the transport network(s) is part of the decision-making process for people when they are choosing a residential location.

Of the available evidence covering the issue of relative mobility, most authors consider it somewhat tangentially. Much of the empirical evidence in the UK on this topic is based on data from Oxfordshire. For example, Headicar (1997) states that the effects of greater mobility are evident in the way people exploit the greater opportunities available within and between established areas of development. In terms of travel distance this is particularly important where it involves travel between urban areas. The disproportionately high rates of traffic growth on the motorway network are a manifestation of this trend (see earlier discussion in Chapter 4).

The functional shift away from self-contained towns in Oxfordshire towards connected settlements within urbanised regions can be seen in the changing distribution of work trip lengths. Between 1975/76 and 1993/95, the proportion of commuting journeys less than five miles fell from 65% to 55%, whilst those over five miles correspondingly increased from 35% to 45%. Once journeys involve travel between towns - particularly where they utilise sections of the motorway network - the individual journey distances tend to become exceptionally long. Thus commutes of 10 miles or more represent only 23% of all work journeys, but contribute to almost two thirds of the total travel distance. Particular locations therefore enable long distance commuting (and other trip types) and attract certain types of (mobile) people. They develop a certain type of 'mobility niche'.

Owens (1998) adds a further caveat - the relative efficiency of different land use patterns depends on people's mobility. If mobility is high, travel behaviour is not very sensitive to land use patterns. Owens therefore requests caution when examining the potential for land use planning in reducing travel. She states that reducing the physical separation of activities is often a necessary but rarely a *sufficient* condition for reducing the amount of travel. Critically the strength of the relationship between land use and transport depends on assumptions about mobility (and other policies). In some areas, land use may have very little impact on travel behaviour; in others, variations in the amount of travel may be more dependent on land use patterns and urban form. So - a difficult issue to grasp - yet one that might explain differences in research results between (typically) compact urban forms in the UK and more dispersed forms for example in the US. Relative mobillity patterns (and the added cultural/attitudinal aspects that may run alongside - Californians think nothing of commuting 90 minutes in each direction to work, while those in the UK may have lower distance thresholds) - are likely to be an important factor in the reasoning behind travel behaviour.

Hence, the key issues for this thesis, in terms of relative mobility and travel behaviour, are:

- How do differences in relative mobility affect the travel behaviour patterns of the new household occupiers surveyed in 1998 and 2001?

EVIDENCE FROM SURREY: RELATIVE LEVELS OF MOBILITY AND TRAVEL BEHAVIOUR

These issues are examined by considering the impact of surrounding levels of mobility – using (1) average journey to work length by ward and (2) average journey to work mode share by car by ward (both using 2001 census data) – on new household occupier travel behaviour. The latter is measured in terms of journey to work energy consumption, journey distance, journey time and mode share percentage by car.

Figure 5.69: *Relative Levels of Mobility (JTW Length by Ward)*

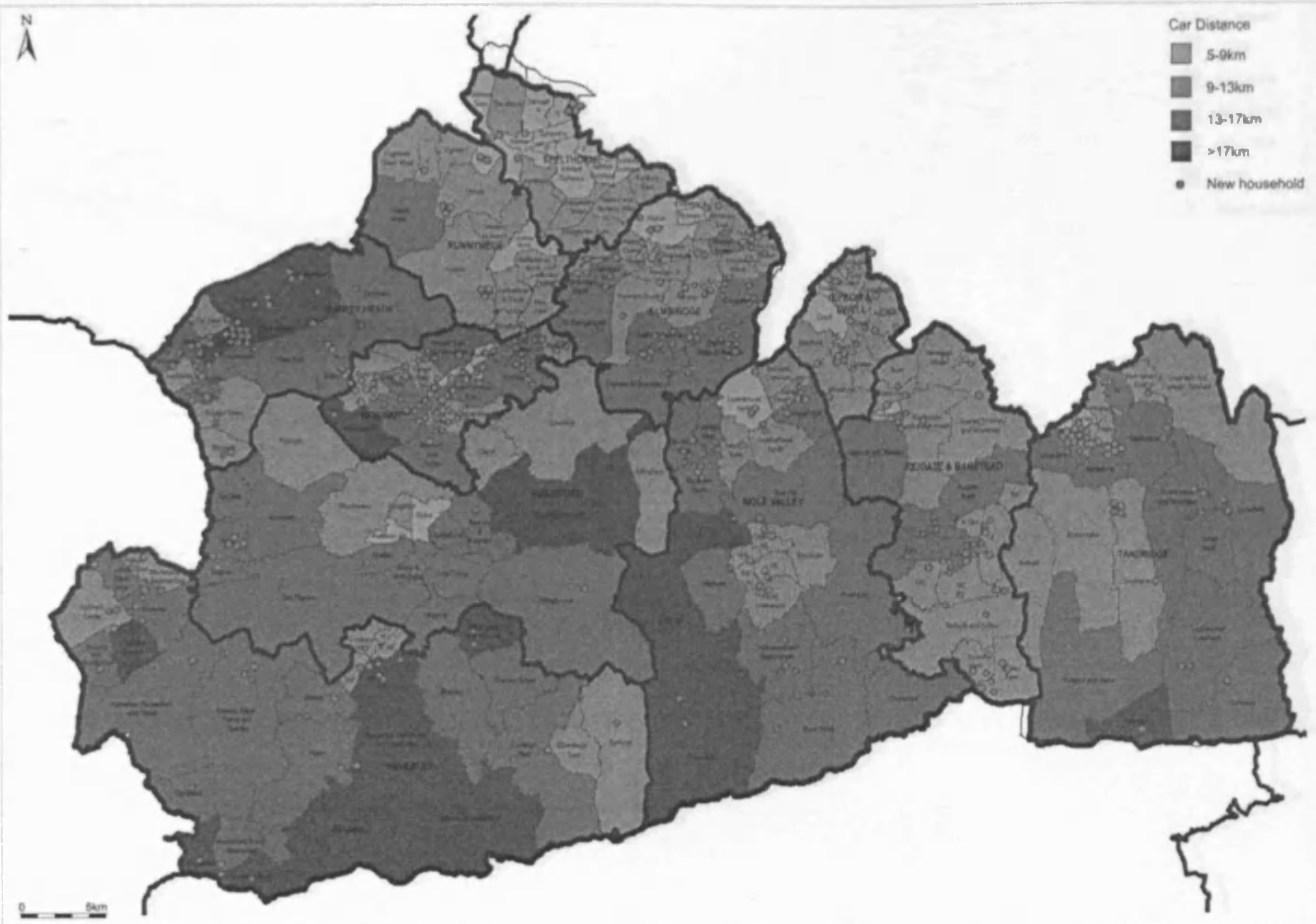
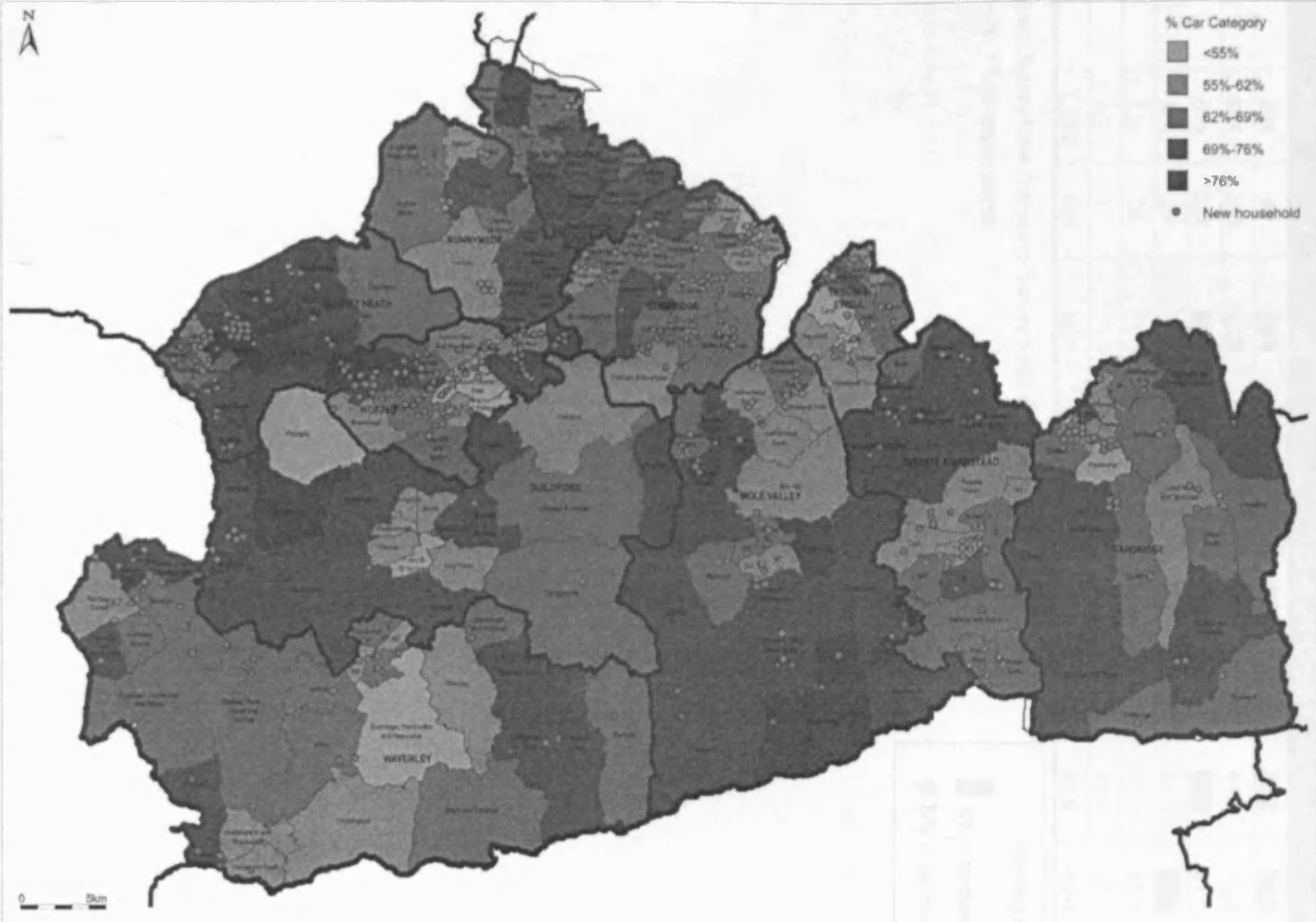


Figure 5.70: *Relative Levels of Mobility (JTW Mode Share by Ward)*



Surrounding Ward Journey to Work Length

Table 5.31A highlights the differences in surrounding average journey to work length by ward and new household occupier travel behaviour.

Table 5.31A: *Surrounding Levels of Mobility (Journey to Work Length) and Travel Behaviour*

Surrounding Levels of Mobility Average Journey to Work Length (by Ward, km)	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
5-9 km	294	86	49.8	43.2	25.9	24.8	37.8	38.2	74%	68%
9-13 km	604	208	55.7	56.8	28.6	29.1	41.5	42.3	72%	71%
13-17 km	615	202	65.9	64.0	32.4	29.6	44.1	41.0	75%	79%
> 17 km	140	29	75.5	92.2	35.0	36.4	43.0	46.2	80%	85%
17-21 km	136	28	75.5	88.8	34.3	35.4	42.2	45.8	80%	84%
21-25 km	4**	1**	73.1	187.1	58.7	65.1	68.8	57.7	67%	100%
Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	74%	73%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

Y: 5% < sample average

The following issues are evident:

- The vast majority of new households are located in wards where average journey to work lengths are between 9-17km (74% of respondents in 1998 and 78% in 2001).
- There is a clear linear relationship in terms of surrounding mobility and respondent travel behaviour. Where surrounding mobility is low, respondent energy consumption in the commute to work is low; and the reverse also occurs. There is an assumed 'peer effect' in evidence.

Chi-square analysis supports these findings: there is a strong significant relationship between surrounding levels of mobility and energy consumption.

Table 5.31B: *Surrounding Mobility (JTW) and Travel Behaviour*

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
Surrmob-jd-EC98			
Pearson Chi-Square	52.51[p]	4	0.000**
Surrmob-jd-EC01			
Pearson Chi-Square	17.29[q]	4	0.002**
[q] 0 cells (0%) have expected count less than 5. The minimum expected count is 20.59.			

***Chi-square is significant at the 0.01 level.*

**Chi-square is significant at the 0.05 level.*

Figure 5.71: *Surrounding Levels of Mobility (Journey to Work Length) and Travel Behaviour*

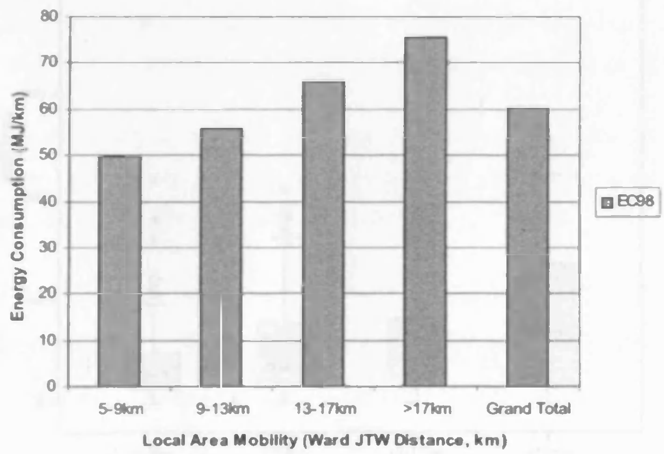


Figure 5.72: *Surrounding Levels of Mobility (JTW Length) and Energy Consumption 1998*

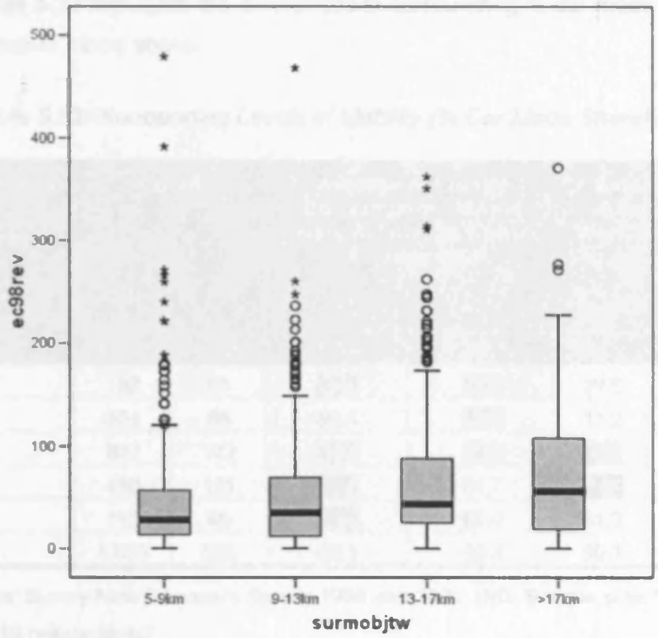
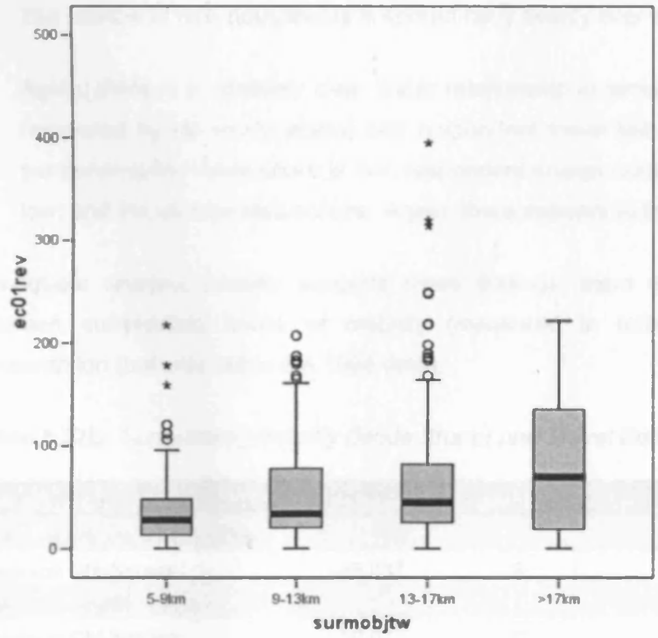


Figure 5.73: *Surrounding Levels of Mobility (JTW Length) and Energy Consumption 2001*



Surrounding Ward Journey to Work Mode Share

Table 5.32 highlights the differences in surrounding % car mode share by ward and new household occupier mode share.

Table 5.32: *Surrounding Levels of Mobility (% Car Mode Share) and Travel Behaviour*

Surrounding Levels of Mobility Average Journey to Work Mode Share (by Ward, % Car)	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance (Km)		Average of Journey to Work Time (Mins)		% Car	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
<55%	192	61	52.8	55.0	29.5	29.5	44.4	45.2	66%	73%
55%-62%	304	85	59.4	64.6	31.2	29.6	44.1	41.3	69%	72%
62%-69%	527	172	53.9	54.1	27.6	26.1	40.8	38.2	72%	69%
69%-76%	480	161	67.7	61.7	32.0	31.0	42.1	43.6	81%	80%
>76%	150	46	68.2	67.0	31.3	[illegible]	38.0	40.3	84%	77%
Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	74%	73%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key
X: 5% > sample average
Y: 5% < sample average

Similar issues are evident using this different type of measurement:

- The sample of new households is spread fairly evenly over the different mode share cohorts.
- Again, there is a relatively clear linear relationship in terms of surrounding mobility (this time measured by car mode share) and respondent travel behaviour (in the 1998 data). Where surrounding car mode share is low, respondent energy consumption in the commute to work is low; and the reverse also occurs. Again, there appears to be a 'peer effect' in evidence.

Chi-square analysis broadly supports these findings: there is a strong significant relationship between surrounding levels of mobility (measured in terms of mode share) and energy consumption (but only within the 1998 data).

Table 5.32B: *Surrounding Mobility (Mode Share) and Travel Behaviour*

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
Surrmob (mode share)-EC98			
Pearson Chi-Square	55.03 [a]	8	0.000**
Surrmob (mode share)-EC01			
Pearson Chi-Square	10.07 [b]	8	0.260
[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 38.97.			
[b] 0 cells (0%) have expected count less than 5. The minimum expected count is 11.03.			

***Chi-square is significant at the 0.01 level.*

**Chi-square is significant at the 0.05 level.*

Figure 5.74: *Surrounding Levels of Mobility (% Car Mode Share) and Travel Behaviour*

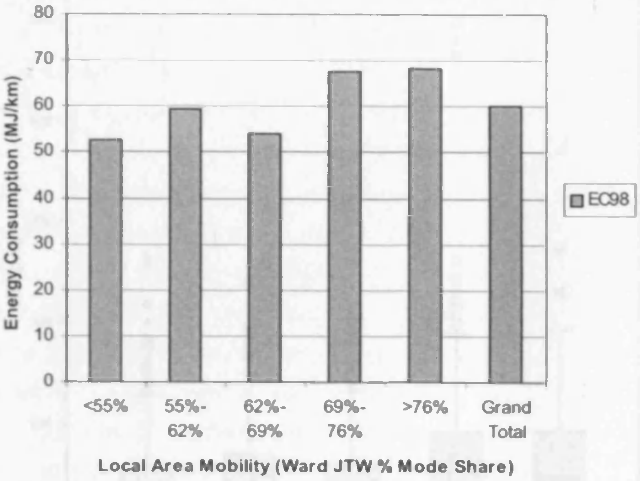


Figure 5.75: *Surrounding Levels of Mobility (Car Mode Share) and Energy Consumption 1998*

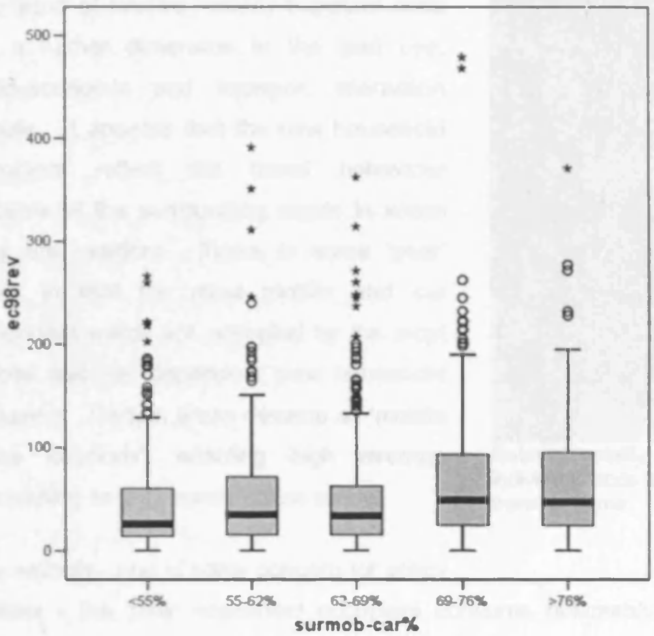
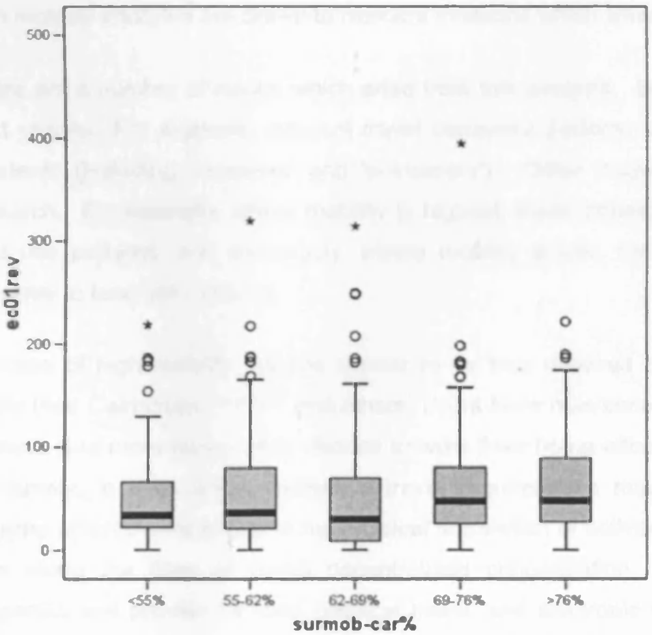


Figure 5.76: *Surrounding Levels of Mobility (Car Mode Share) and Energy Consumption 2001*



Relative mobility: summary thoughts

The issue of relative mobility therefore adds yet a further dimension to the land use, socio-economic and transport interaction debate. It appears that the new household occupiers reflect the travel behaviour patterns of the surrounding wards in which they are resident. There is some 'peer' effect in that the most mobile and car dependent wards are occupied by the most mobile and car dependent new household occupiers. Certain areas develop as 'mobile niche locations', enabling high average commuting energy consumption levels.

Relative mobility: when the neighbours are mobile, the individual tends towards high energy consumption travel patterns.

Interestingly - and of some concern for policy makers - the 'new' household occupiers consume noticeably more energy and are more car dependent than the existing ward residents. This is so even in the existing highly mobile locations. Travel behaviour patterns are getting ever more so energy intensive. This peer affect could have a number of explanations, the most plausible being that individuals who wish to continue with their high mobility lifestyles are drawn to resident locations which allow them to do this.

There are a number of issues which arise from this analysis. Some of these are developed in the next chapter. For example, different travel behaviour patterns are generated by different types of residents (including 'inmovers' and 'outmovers'). Other issues could be the subject of further research. For example, where mobility is highest, travel behaviour is likely to be less sensitive to land use patterns, and conversely, where mobility is low, travel behaviour is likely to be more sensitive to land use patterns.

In areas of high mobility, people appear to be less deterred by distance: the death of distance thesis (see Cairncross, 1997[47] and others) might have relevance here, particularly in years to come as more and more people may choose to work from home either partly or wholly during the week. Perversely, in such areas, individual travel requirements may be better reduced by land use patterns which *do not* minimise the physical separation of activities. An example might be land use form along the lines of (very) decentralised concentration, where remote, local centres are supported and provide for local physical travel, and electronic means provide for longer distance communication. Hence the difficulty in generalisation; we miss out on contextualisation. All areas are different, and all areas perform different roles with particular niches.

[47] Cairncross (1995, p.39) famously prophesised that "the death of distance will mean that any activity that relies on a screen or telephone can be carried out anywhere in the world". Others have commented along similar lines, for example Castells (1989, p.33) "the emergence of a space of flows which dominates the historically constructed space of places"; and Gates himself (1995, p.4/5) "there will be a day, not far distant, when you will be able to conduct business, study, explore the world and its cultures, call up any great entertainment, make friends, attend neighbourhood markets, and show pictures to distant relatives, without leaving your desk or armchair".

5.2.6 Dual Income Households and Stretch Commuting

The trend towards multiple wage-earner households has contributed towards recent changes in journey to work travel behaviour patterns, and phenomena such as jobs-housing imbalances. Cervero (1989a) notes that where there is a clear distinction between the primary and secondary wage-earner, as in the 'traditional' family structure, most families may be expected to locate with reference to the breadwinner's workplace, with the other spouse finding work nearby. Where couples earn comparable salaries, however, the residential location choice is less likely to be one-sided in favour of the single person. Families may choose to live somewhere in between the workplaces of both wage-earners in order to balance out commuting distances. Unless a region has a large share of households where both wage earners work in the same vicinity, a certain degree of jobs-housing imbalance is inevitable. In the case of California's Silicon Valley, most members of dual wage-earner households do not work near each other: 57% work in different cities.

Recent research in the USA has considered the topic of long distance commuting, and termed the phenomenon as 'stretch commuting' (US Department of Transportation, 2004[48]). About 3.3 million Americans travel 50 miles or more one way to get to work - and they commute these distances 329 million times a year, according to National Household Travel Survey (NHTS) findings Of the 61.6 billion commutes to and/or from work each year, just under one out of every 200 trips is a stretch commute.

Stretch commuters are mostly male. Women - 52% of the population - only make 16% of stretch commuting trips. Nearly three out of five stretch commuting trips are made by someone from a household with an annual income of at least $50,000. Slightly more than two out of five U.S. households earn that much. Stretch commutes are disproportionately rural - two out of every five stretch commutes start in rural areas. Eight out of 10 (81%) stretch commutes are 50 to 99 miles in length one way. For these commuters, stretch commuting is nearly an everyday occurrence - about two-thirds of the 50- to 99-mile one-way commutes are made at least four days each week. While one out of five (19%) stretch commutes is at least 100 miles, more than one in 20 (6%) can be called 'super-stretch commutes', trips to work of 200 miles or more, one-way; and these latter trips are usually made once a week by air.

So, in summary, the key issues for this thesis, in terms of dual income households, stretch commuting and travel behaviour, are:

- How do dual income households affect the travel behaviour patterns of the new household occupiers? Do they travel longer distances, consuming greater energy consumption?
- Is there evidence of stretch commuting in the new household occupier data? What cohorts make up stretch commuters in Surrey?

[48] See USA Transportation Research Board of The National Academies website for more details: www.gulliver.trp.org

EVIDENCE FROM SURREY: DUAL-INCOME HOUSEHOLDS AND STRETCH COMMUTING AND TRAVEL BEHAVIOUR

Table 5.33 highlights the differences in new household occupier travel behaviour for dual income households.

Table 5.33: *Dual Income Households and Travel Behaviour*

Number of workers per household	Count		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Distance, Km		Average of Journey to Work Time, Mins		% Car	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
Single	213	62	52.3	51.9	24.9	22.8	35.8	32.2	77%	82%
Dual	1,195	390	62.2	62.2	31.7	31.0	43.9	43.6	72%	66%
Multiple	245	73	56.8	50.8	26.6	23.6	37.7	36.9	67%	64%
Total	1,653	525	60.1	59.4	30.1	29.0	41.9	41.4	72%	68%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key

X: 5% > sample average

Y: 5% < sample average

The following issues are evident:

- The vast majority of new households have two or employees workers resident there; few are home to just one employee (13% of respondents in 1998 and 12% in 2001).

- There is a relatively clear distinction with dual income households and travel behaviour. Households with two employees are the higher energy consumers: 3% higher than the sample average in 1998. Households with single incomes consume 13% less than the sample average.

Correlation analysis however does not support these findings. There is no significant relationship between dual income households and travel behaviour.

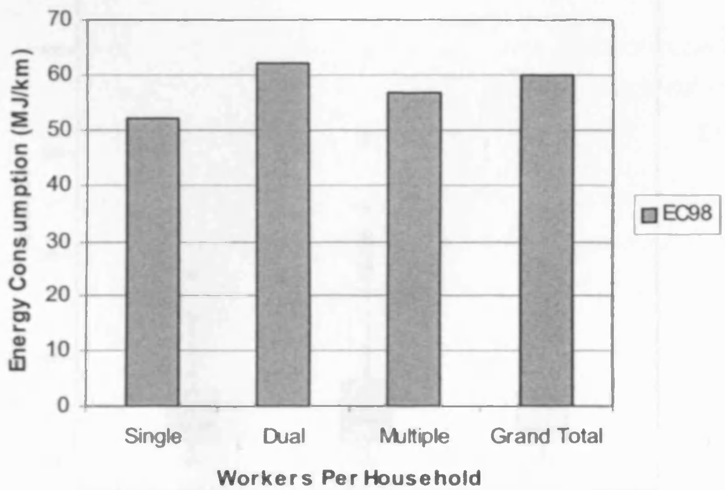
Table 5.33B: *Dual Income Households and Travel Behaviour*

Variable	Correlation	EC98	EC01	JD98	JD01
Dual income HH	Pearson Correlation	-0.008	-0.024	0.011	-0.001
	Sig. (2-tailed)	0.757	0.592	0.66	0.981

***Correlation is significant at the 0.01 level (2-tailed)*

**Correlation is significant at the 0.05 level (2-tailed)*

Figure 5.77: *Dual Income Households and Travel Behaviour*



A likely reason for the larger travel distance for dual income households is that people are choosing their household location somewhere between the two (or more) workplace locations. The result of this is that individual commute distances are high. The additional part of the commute is also affected by other factors influencing the choice of house location, e.g. surrounding environment, location of family, friends and schools, etc.

Figure 5.78: *Dual Income Households and Energy Consumption 1998*

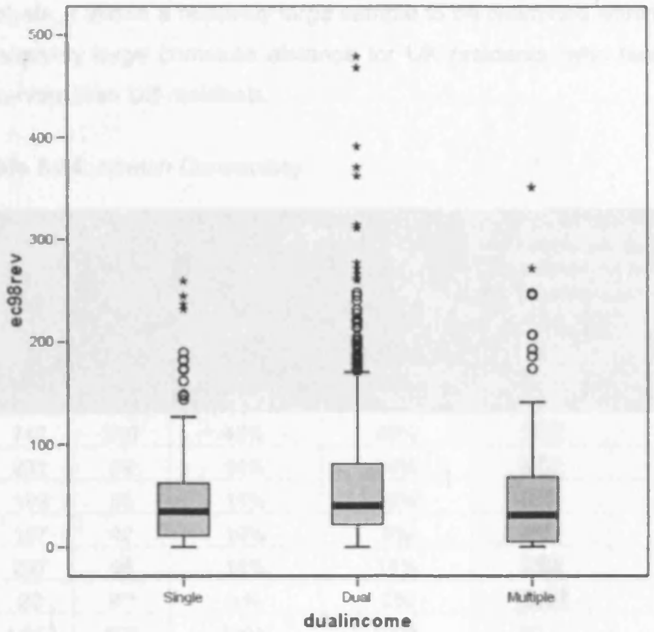


Figure 5.79: *Dual Income Households and Energy Consumption 2001*

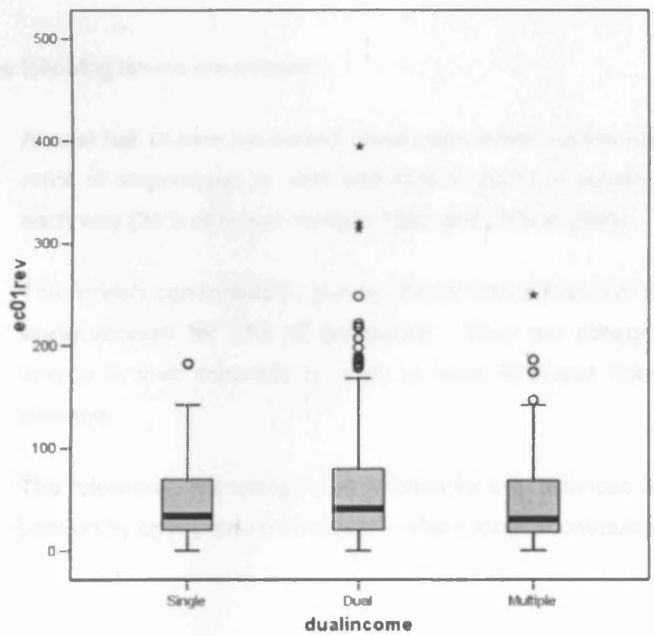


Table 5.34 highlights the incidence of stretch commuting (defined within this analysis as commutes >50km). Note: although this is a shorter distance than the >50 miles used in much of the US-based analysis, it allows a relatively large sample to be examined within the Surrey NHOS data, and is still a relatively large commute distance for UK residents, who tend to be less used to driving large distances than US residents.

Table 5.34: *Stretch Commuting*

JTW Journey Lengths	Count		% Share		Average of Energy Consumption, MJ/jtw (Index Relative to Sample Average 100)		Average of Journey to Work Time, Mins		% Car	
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
0-20 km	747	240	45%	46%	28.5	27.1	15.8	15.2	85%	77%
20-30 km	231	84	14%	16%	69.3	68.1	35.0	34.8	94%	74%
30-40 km	189	55	11%	10%	90.0	80.6	46.7	50.2	86%	73%
40-50 km	167	42	10%	8%	84.2	81.9	64.3	68.8	54%	59%
50-100 km	297	96	18%	18%	95.6	102.4	90.8	88.7	38%	49%
>100 km	22	8**	1%	2%	250.4	162.6	131.5	122.7	33%	57%
Total	1,653	525	100%	100%	60.1	59.4	41.9	41.4	72%	68%

Data: Surrey New Occupiers Survey 1998 and 2001. (NB. Sample size: *<20, **<10 respondents)

Shading Key
X: 5% > sample average
Y: 5% < sample average

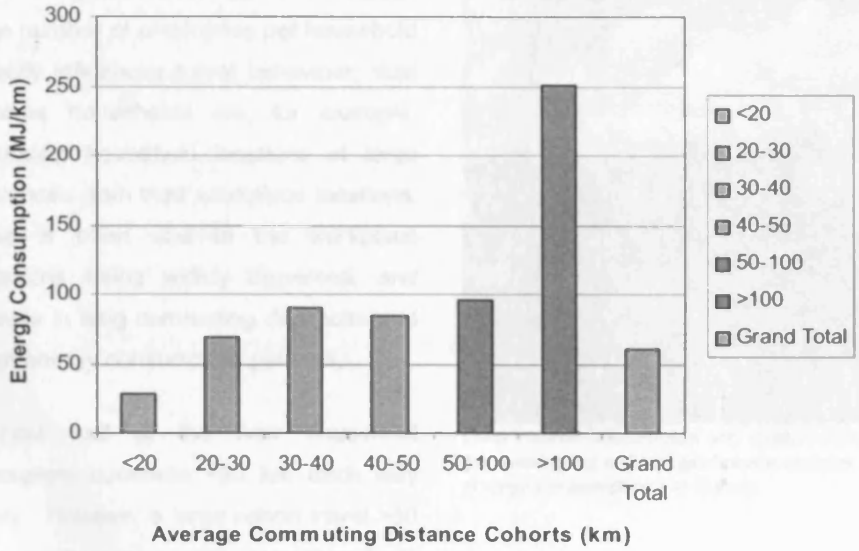
The following issues are evident:

- Almost half of new household commuters travel <20km each way in their daily travel to work (45% of respondents in 1998 and 46% in 2001). A substantial number however travel >40km each way (29% of respondents in 1998 and 28% in 2001).

- The stretch commuters in Surrey (those that travel over 50km each way in their journey to work) account for 21% of commutes. They are consuming a disproportionate amount of energy in their commute to work: at least 40% and rising to 300% more than the sample average.

- The apparently flat energy consumption for trip distances 30-100km reflects the commuting to London by public transport cohort – where longer commutes are less energy intensive.

Figure 5.83: *Stretch Commuting and Travel Behaviour*



Of the stretch commuters, a disproportianate number are from the higher income bands; with much fewer from the lower income bands. For example:

- Stretch commuters with household incomes <£35k = 14% (relative to the total NHOS sample, which has stretch commuters accounting for 20%).
- Stretch commuters with household incomes £35k-£100k = 65% (NHOS sample 66%).
- Stretch commuters with household incomes >£100k = 21% (NHOS sample 14%).

Stretch commutes also have a disproportionate rural household origin (as car commuters) and town centre household origin (as rail commuters).

- Stretch commuters from rural areas = 22% (NHOS sample 17%)
- Stretch commuters from rest of urban area = 57% (NHOS sample 68%)
- Stretch commuters from town centre = 21% (NHOS sample 15%)

Dual Income Households and Stretch Commuting: Summary Thoughts

The findings in Surrey appear to be clear. The number of employees per household greatly influences travel behaviour; dual income households are, for example, choosing household locations at large distances from their workplace locations. This is often due to the workplace locations being widely dispersed, and results in long commuting distances and high energy consumption patterns.

Dual income households and stretch commuting: accounting for a disproportionate amount of travel (and energy consumption) in Surrey.

Almost half of the new household occupiers commute <20 km each way daily. However a large cohort travel >50 km each way - with correspondingly energy consumption patterns. The existence of these stretch commuters represents a dilemma for policy makers: PPG13 at the moment doesn't focus on this phenomenon. However future editions may wish to discourage such travel behaviour, particularly if reducing energy consumption becomes a more important policy objective. Pricing mechanisms (increasing the cost of travel) could reasonably be used to implement such a changed policy rationale.

This thesis goes no further here: the analysis doesn't consider the reasoning behind the growth in dual income households and the resulting travel behaviour. Such behavioural analysis would be a useful extension to this research, for example, examining income/house price mismatches and individual lifestyle choices and impacts on travel.

5.3 Socio-Economic Conclusions

The final section below draws together the findings of this chapter on socio-economic and attitudinal characteristics and travel behaviour. It focuses on the high and low energy consuming groups and also draws together previous bi-variate correlation analysis.

High and Low Energy Consumers

The high and low energy consumers are defined as those cohorts consuming at least 10% more or less than the sample average (see Figure 5.81).

Figure 5.81: *The High and Low Energy Consuming Cohorts*

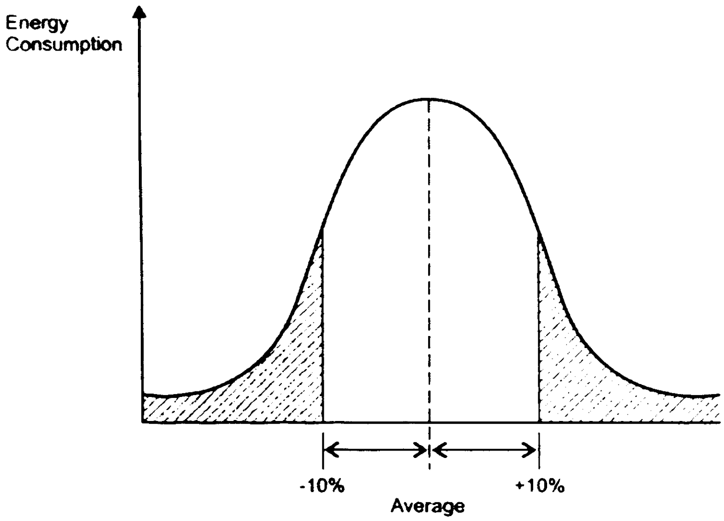


Table 5.35 and Figure 5.82 show the high and low energy consumers. A number of groups consume >10% more than the sample average (in 1998). These are outlined below:

- Car availability: 2, 3 and over
- Company car ownership
- House value: > £600k
- House income: £70k-£100k and >£150k
- Qualification: A level

The differential in travel behaviour between socio-economic groups appears less than that between land use categories (there are a number of particular land use categories that consume 25% more than the sample average, e.g. particular types of journey origins-destinations, see page 155).

Many of the higher energy consuming groups, as would be expected intuitively, are either the higher income groups, or those on relatively low incomes (who presumably cannot afford a house nearer to their workplace location).

Table 5.35: *The Socio-Economic High and Low Energy Consumers*

High and Low Energy Consuming Cohorts (At Least +/-10% Relative to Sample Average)	Count		Average of Energy Consumption (MJ/jtw)		Index: Energy Consumption Relative to Sample Average	
	1998	2001	1998	2001	1998	2001
House Tenure						
Owner Occ (Out)	162	54	52.1	58.4	-13%	-2%
House type						
PB Flat	127	30	45.9	59.3	-24%	0%
House size (bedrooms)						
1	86	13*	41.0	60.1	-32%	+1%
2	331	112	53.7	60.1	-11%	+1%
3	560	177	63.3	53.2	+5%	-10%
5 and over	199	57	64.3	66.8	+7%	+12%
No.of children						
1	247	64	60.9	66.3	+1%	+12%
2	242	56	58.6	82.6	-3%	+39%
3 and over	78	18*	53.5	53.6	-11%	-10%
Car availability						
1	111	95	49.4	50.6	-18%	-15%
2	188	157	68.2	70.6	+13%	+19%
3 and over	22	19*	68.8	86.0	+14%	+45%
Company car ownership						
No	459	422	53.2	53.8	-12%	-9%
Yes	105	100	77.3	82.0	+29%	+38%
Household Income						
<£20k	36	23	49.7	68.1	-17%	+15%
£35-50k	94	82	57.0	52.9	-5%	-11%
£70-100k	70	63	74.0	74.4	+23%	+25%
£100-150kk	37	31	65.6	70.2	+9%	+18%
£>150k	31	24	69.0	79.9	+15%	+35%
House Value						
£200-400k	1385	305	58.8	51.9	-2%	-13%
£400-600k	196	164	66.6	68.5	+11%	+15%
>£600k	21	18	81.4	99.5	+35%	+67%
Sex						
Female	707	189	54.1	64.2	-10%	+8%
Male	935	274	64.7	30.5	+8%	-49%
Age						
17-24	92	14*	44.1	31.2	-27%	-48%
Over retirement	10*	10*	25.8	32.2	-57%	-46%
Marital status						
Single	238	62	50.5	48.5	-16%	-18%
Widowed	18*	6**	52.1	28.1	-13%	-53%
Occupation						
Employed PT	164	65	38.5	43.8	-36%	-26%
Self Employed	125	42	38.6	65.1	-36%	+10%
Qualification						
A level	92	69	68.3	65.9	+14%	+11%
O level	164	139	57.0	52.3	-5%	-12%
Grand Total	**1,653**	**525**	**60.1**	**59.4**	**0%**	**0%**

High and Low Energy Consuming Cohorts *(At Least +/-10% Relative to Sample Average)*	Count	Average of Energy Consumption (MJ/jtw)	Index: Energy Consumption Relative to Sample Average
	2001	2001	2001
Attitude			
Att-(E)-CATEG			
Strongly agree	50	46.5	-22%
Att-(PT)-CATEG			
Agree	81	51.9	-13%
Strongly disagree	16*	66.1	+11%
Att-(Res)-CATEG			
Strongly agree	141	66.7	+12%
Disagree	25	69.1	+16%
Att-(Mob)-CATEG			
Disagree	5**	37.2	-37%
Strongly disagree	2**	165.0	+178%
Att-(Time)-CATEG			
Strongly agree	116	69.4	+17%
Att-(Urb Vil)-CATEG			
Disagree	59	66.8	+12%
Strongly disagree	1**	50.9	-14%
Att-(TM)-CATEG			
Strongly agree	14*	51.4	-13%
Disagree	138	66.7	+12%
Strongly disagree	19*	77.7	+31%
Grand Total	**525**	**59.4**	**0%**

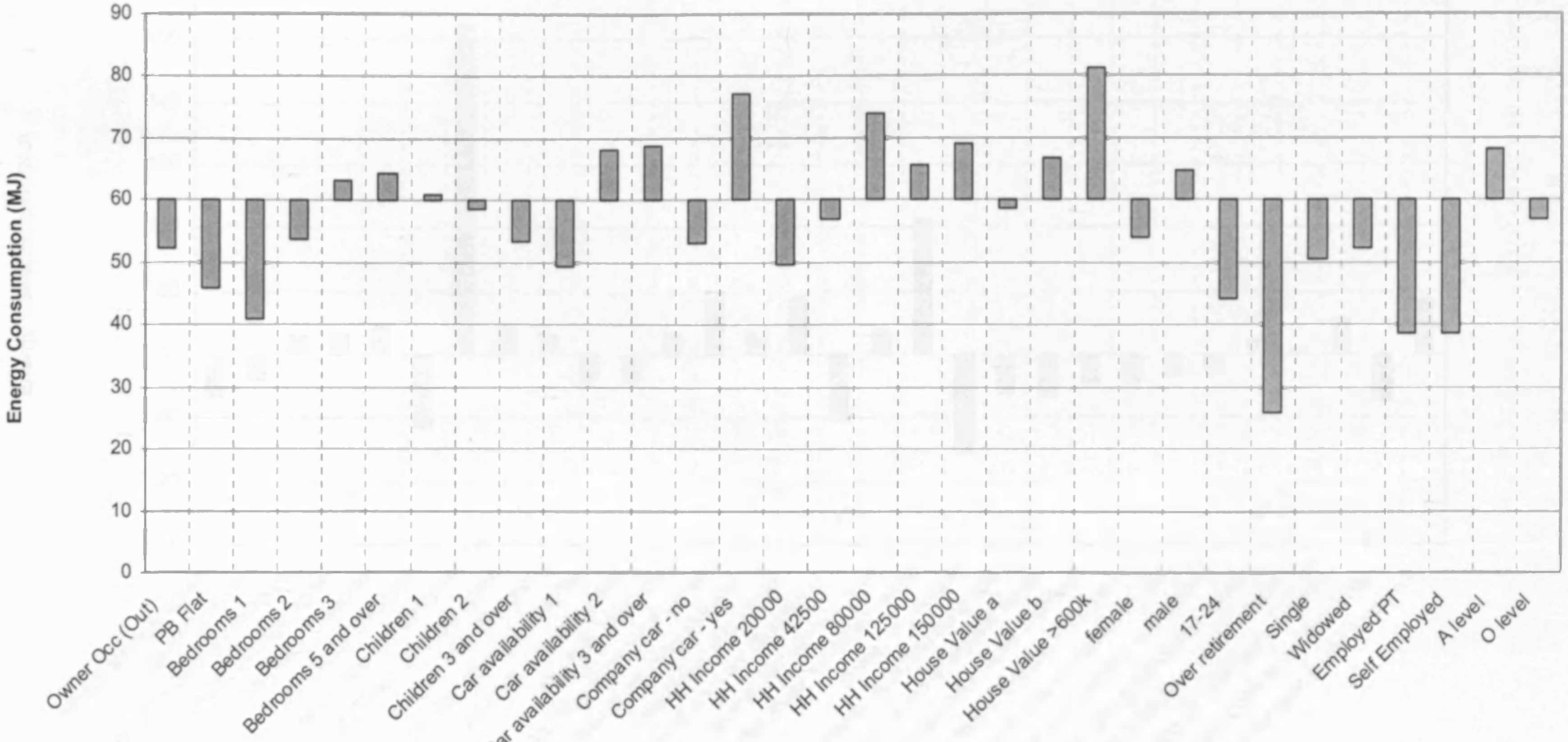
High and Low Energy Consuming Cohorts *(At Least +/-10% Relative to Sample Average)*	Count	Average of Energy Consumption (MJ/jtw)	Index: Energy Consumption Relative to Sample Average
	2001	2001	2001
Attitude to home and home location			
Preferred area of residence			
Very satisfied	147	67.1	+13%
Dissatisfied	16*	78.1	+31%
Very dissatisfied	9**	39.6	-33%
Preferred Home Location			
Remote rural area	34	67.6	+14%
Major suburban centre	13*	102.5	+73%
City centre	9**	28.9	-51%
Preferred Type of Home			
Detached bungalow	30	47.4	-20%
Grand Total	**525**	**59.4**	**0%**

High and Low Energy Consuming Cohorts *(At Least +/-10% Relative to Sample Average)*	Count		Average of Energy Consumption (MJ/jtw)		Index: Energy Consumption Relative to Sample Average	
	1998	2001	1998	2001	1998	2001
Reasons for moving from previous home						
Smaller House	88	22	52.0	46.8	-14%	-21%

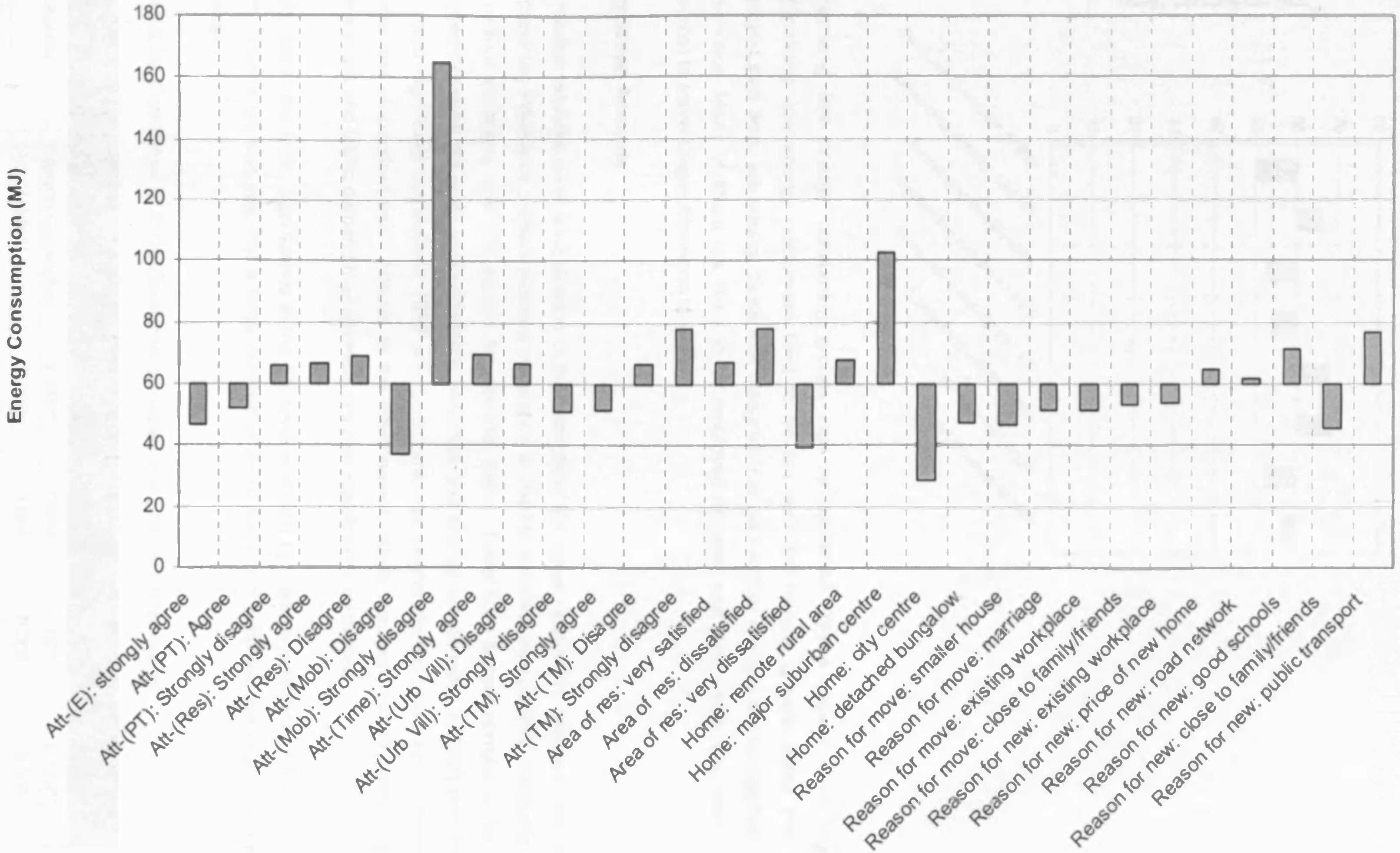
Marriage	81	19*	66.4	51.5	10%	-13%
Existing Workplace	59	18*	69.6	51.4	16%	-13%
Close to Family/Friends	36	12*	94.4	53.5	57%	-10%
Reason for choosing new location						
Existing Workplace	241	74	53.2	54.2	-12%	-9%
Price of New Home	113	32	52.6	65.0	-13%	+9%
Road Network	101	35	80.3	61.8	34%	+4%
Good Schools	88	18*	63.7	71.5	6%	+20%
Close to Family/Friends	86	24	67.2	45.7	12%	-23%
Public Transport	64	22	44.1	77.0	-27%	+30%
Surrounding Mobility (JTW length)						
5-9km	294	86	49.8	43.2	-17%	-27%
13-17km	615	202	65.9	64.0	10%	+8%
Surrounding Mobility (Mode share, car)						
<55%	192	61	52.8	55.0	-12%	-7%
62-69%	527	172	53.9	54.1	-10%	-9%
69-76%	480	161	67.7	61.7	13%	+4%
>76%	150	46	68.2	67.0	13%	+13%
Dual Income Households						
Single	213	62	52.3	51.9	-13%	-13%
Multiple	245	73	56.8	50.8	-6%	-15%
Stretch Commuters						
<20	747	240	28.5	27.1	-53%	-54%
20-30	231	84	69.3	68.1	15%	+15%
30-40	189	55	90.0	80.8	50%	+36%
40-50	167	42	84.2	81.9	40%	+38%
50-100	297	96	95.6	102.4	59%	+72%
>100	22	8**	250.4	162.6	316%	+174%
Grand Total	**1,653**	**525**	**60.1**	**59.4**	**0%**	**0%**

Figure 5.82: *The Socio-Economic High and Low Energy Consumers*

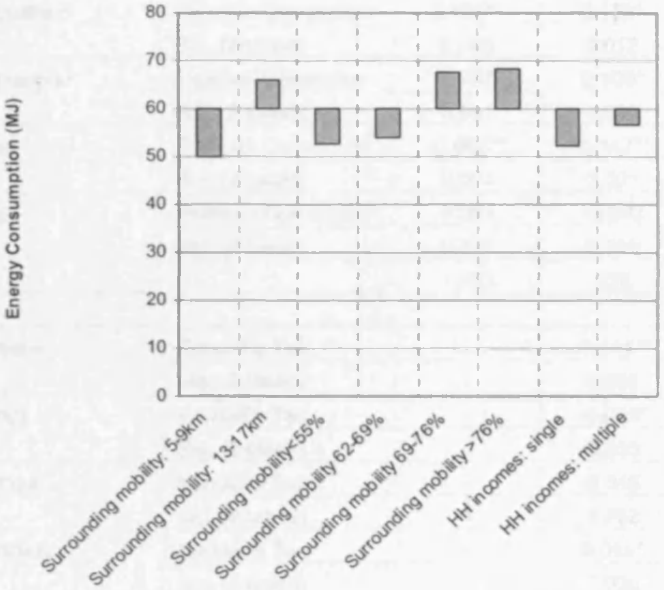
A. Socio-Economic Characteristic



B. Attitude


Energy Consumption (MJ)
180
160
140
120
100
80
60
40
20
0
Att-(E): strongly agree
Att-(PT): Agree
Att-(PT): Strongly disagree
Att-(Res): Strongly agree
Att-(Res): Disagree
Att-(Mob): Disagree
Att-(Mob): Strongly disagree
Att-(Time): Strongly agree
Att-(Urb Vill): Disagree
Att-(Urb Vill): Strongly disagree
Att-(TM): Strongly agree
Att-(TM): Disagree
Att-(TM): Strongly disagree
Area of res: very satisfied
Area of res: dissatisfied
Area of res: very dissatisfied
Home: remote rural area
Home: major suburban centre
Home: city centre
Home: detached bungalow
Reason for move: smaller house
Reason for move: marriage
Reason for move: existing workplace
Reason for move: close to family/friends
Reason for new: existing workplace
Reason for new: price of new home
Reason for new: road network
Reason for new: good schools
Reason for new: close to family/friends
Reason for new: public transport

C. Other (Surrounding Mobility, etc.)



Conversely, low energy consuming groups can be identified. These, again, have logical explanations: low energy consumers tend to be the very low income groups, those that are employed part time, are young, those that disagree that car mobility is important or that they are workaholics. Many of these are likely to be employed in lower skill jobs - with less need (and resource) to travel longer distances to work.

Correlation Analysis

Correlation analysis gives an indication of the strength of the linear association between variables. As previous, Pearson's product moment correlation is used to examine interval data, Kendall's tau for ordinal variables, and Chi square for nominal data. Table 5.36 shows correlation factors between between the main socio-economic variables and energy consumption in 1998 and 2001. The most significant correlations 1998 are: bedrooms, car availability, company car, household income and respondent sex. Attitude to the environment, public transport, mobility, time, urban environment and traffic demand management are also significantly correlated.

Again, within the table, significance at the 5% level is shown by * and significance at the 1% level by **. Hence we can see that a large number of socio-economic variables are related to travel behaviour.

Table 5.36: *Correlation of Socio-Economic Variables and Energy Consumption*

Socio-Economic Variable	Correlation	EC98	EC01	JD98	JD01
bedrooms	Pearson Correlation	0.088**	0.070	0.157**	0.128**
	Sig. (2-tailed)	0.000	0.098	0.000	0.003
children	Pearson Correlation	-0.022	0.072	-0.012	0.015
	Sig. (2-tailed)	0.356	0.090	0.622	0.723
caravail	Pearson Correlation	0.134*	0.225**	0.095	0.071

	Sig. (2-tailed)	0.012	0.000	0.086	0.239
compcar	Pearson Correlation	-0.183**	-0.223**	-0.063	-0.071
	Sig. (2-tailed)	0.000	0.000	0.135	0.103
housinco	Pearson Correlation	0.125**	0.123*	0.166**	0.225**
	Sig. (2-tailed)	0.005	0.012	0.000	0.000
houseval	Pearson Correlation	0.087	0.109*	0.111	0.107
	Sig. (2-tailed)	0.081	0.046	0.033	0.059
sex	Pearson Correlation	-0.068**	-0.147**	-0.158**	-0.182**
	Sig. (2-tailed)	0.004	0.001	0.000	0.000
age	Pearson Correlation	0.004	-0.043	0.007	-0.045
	Sig. (2-tailed)	0.877	0.319	0.787	0.304
N		1,653	525	1,653	525

attenv	Kendall's Tau	-	-0.114**	-	-0.024
	Sig. (2-tailed)	-	0.006	-	0.571
attpt	Kendall's Tau	-	-0.085*	-	-0.053
	Sig. (2-tailed)	-	0.039	-	0.213
attres	Kendall's Tau	-	0.046	-	0.057
	Sig. (2-tailed)	-	0.262	-	0.178
attmob	Kendall's Tau	-	0.089*	-	0.053
	Sig. (2-tailed)	-	0.035	-	0.218
atttime	Kendall's Tau	-	0.084*	-	0.002
	Sig. (2-tailed)	-	0.043	-	0.957
attuv	Kendall's Tau	-	-0.084*	-	-0.061
	Sig. (2-tailed)	-	0.038	-	0.141
attpm	Kendall's Tau	-	-0.087*	-	-0.013
	Sig. (2-tailed)	-	0.030	-	0.757
attwork	Kendall's Tau	-	-0.007	-	0.004
	Sig. (2-tailed)	-	0.862	-	0.922
N		-	361	-	361

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Chi-square analysis confirms there is a relationship between house tenure, house type, company car ownership, sex, occupation, reason for moving and surrounding mobility and energy consumption in 1998; and company car ownership, sex and surrounding mobility and energy consumption in 2001, using a significance level of 0.01.

Other variables are significant at lower thresholds, for example, house type and tenure and energy consumption in 2001 are significant at 0.05.

Table 5.37: *Chi-Squares for Socio-Economic Variables and Energy Consumption*

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
House Ten-EC98			
Pearson Chi-Square	38.85 [a]	4	0.000**
Likelihood Ratio	40.84	4	0.000
Linear-by-Linear Association	3.18	1	0.074
[a] 0 cells (0%) have expected count less than 5. The minimum expected count is 42.53.			
House Ten-EC01			
Pearson Chi-Square	3.32 [b]	4	0.505
Likelihood Ratio	3.39	4	0.495
Linear-by-Linear Association	0.39	1	0.534
[b] 0 cells (0%) have expected count less than 5. The minimum expected count is 9.07.			
House Typ-EC98			
Pearson Chi-Square	17.71 [c]	6	0.007**
Likelihood Ratio	17.84	6	0.007
Linear-by-Linear Association	4.75	1	0.029
[c] 0 cells (0%) have expected count less than 5. The minimum expected count is 56.80.			
House Typ-EC01			
Pearson Chi-Square	12.53 [d]	6	0.051
Likelihood Ratio	12.08	6	0.060
Linear-by-Linear Association	0.01	1	0.907
[d] 0 cells (0%) have expected count less than 5. The minimum expected count is 13.97.			
Comp. Car-EC98			
Pearson Chi-Square	16.62 [e]	2	0.000**
Likelihood Ratio	15.50	2	0.000
Linear-by-Linear Association	14.75	1	0.000
[e] 0 cells (0%) have expected count less than 5. The minimum expected count is 28.25.			
Comp. Car-EC01			
Pearson Chi-Square	20.44 [f]	2	0.000**
Likelihood Ratio	20.08	2	0.000
Linear-by-Linear Association	20.40	1	0.000
[f] 0 cells (0%) have expected count less than 5. The minimum expected count is 26.2.			
Sex-EC98			
Pearson Chi-Square	6.87 [g]	2	0.032*
Likelihood Ratio	6.90	2	0.032
Linear-by-Linear Association	6.84	1	0.009
[g] 0 cells (0%) have expected count less than 5. The minimum expected count is 181.59.			
Sex-EC01			
Pearson Chi-Square	8.93 [h]	2	0.012*
Likelihood Ratio	9.02	2	0.011
Linear-by-Linear Association	8.78	1	0.003
[h] 0 cells (0%) have expected count less than 5. The minimum expected count is 49.27.			
Marital-EC98			
Pearson Chi-Square	4.43 [i]	4	0.351
Likelihood Ratio	4.54	4	0.338
Linear-by-Linear Association	2.14	1	0.144
[i] 0 cells (0%) have expected count less than 5. The minimum expected count is 31.07.			
Marital-EC01			
Pearson Chi-Square	6.41 [j]	4	0.171
Likelihood Ratio	7.11	4	0.130
Linear-by-Linear Association	2.37	1	0.124
[j] 0 cells (0%) have expected count less than 5. The minimum expected count is 10.05.			

Occup-EC98			
Pearson Chi-Square	19.86 [k]	2	0.000**
Likelihood Ratio	21.62	2	0.000
Linear-by-Linear Association	19.81	1	0.000
[k] 0 cells (0%) have expected count less than 5. The minimum expected count is 45.03.			
Occup-EC01			
Pearson Chi-Square	3.21 [l]	4	0.524
Likelihood Ratio	3.26	4	0.515
Linear-by-Linear Association	0.01	1	0.908
[l] 0 cells (0%) have expected count less than 5. The minimum expected count is 13.43.			
Qualif-EC98			
Pearson Chi-Square	9.01 [l]	6	0.173
Likelihood Ratio	9.51	6	0.147
Linear-by-Linear Association	0.01	1	0.939
[l] 0 cells (0%) have expected count less than 5. The minimum expected count is 13.75.			
Qualif-EC01			
Pearson Chi-Square	4.06 [m]	6	0.668
Likelihood Ratio	4.13	6	0.660
Linear-by-Linear Association	0.14	1	0.706
[m] 0 cells (0%) have expected count less than 5. The minimum expected count is 9.60.			
Reasonch-EC98			
Pearson Chi-Square	4.98 [n]	8	0.759
Likelihood Ratio	5.17	8	0.739
Linear-by-Linear Association	0.00	1	0.978
[n] 0 cells (0%) have expected count less than 5. The minimum expected count is 40.29.			
Reasonch-EC01			
Pearson Chi-Square	1.97 [o]	8	0.982
Likelihood Ratio	2.00	8	0.981
Linear-by-Linear Association	0.41	1	0.524
[o] 0 cells (0%) have expected count less than 5. The minimum expected count is 8.01.			
Reasonmov-EC98			
Pearson Chi-Square	18.71 [p]	8	0.017*
Likelihood Ratio	18.53	8	0.018
Linear-by-Linear Association	1.56	1	0.212
[p] 0 cells (0%) have expected count less than 5. The minimum expected count is 45.08.			
Reasonmov-EC01			
Pearson Chi-Square	23.41 [q]	20	0.269
Likelihood Ratio	23.46	20	0.267
Linear-by-Linear Association	1.71	1	0.191
[q] 0 cells (0%) have expected count less than 5. The minimum expected count is 6.01.			
Surrmob-jd-EC98			
Pearson Chi-Square	52.51 [p]	4	0.000**
Likelihood Ratio	53.10	4	0.000
Linear-by-Linear Association	50.38	1	0.000
[p] 0 cells (0%) have expected count less than 5. The minimum expected count is 76.92.			
Surrmob-jd-EC01			
Pearson Chi-Square	17.29 [q]	4	0.002**
Likelihood Ratio	18.30	4	0.001
Linear-by-Linear Association	15.85	1	0.000
[q] 0 cells (0%) have expected count less than 5. The minimum expected count is 20.59.			

N=1,653 in 1998 and 525 in 2001

***Chi-square is significant at the 0.01 level.*

**Chi-square is significant at the 0.05 level.*

The implications of these findings are again important. A wide range of socio-economic characteristics are significantly associated with travel behaviour – either in terms of energy consumption, journey distance, time or mode. Some of these, such as income, have been well researched previously and are relatively well understood in terms of potential impacts. Others, such as attitudes to travel or relative mobility "peer effects", are much less well researched and understood.

It appears that the rationale for travel behaviour is complex. So too must be our analysis of the contributory factors behind travel – especially if we take that step further to seek to manipulate travel patterns at the aggregate level. Socio-economic characteristics are quite different to urban form characteristics in terms of their "malleability" as policy tools: politically and socially it would be unacceptable to reduce incomes in the name of reducing travel. However, there are more subtle ways as to achieving such objectives and in which we can reasonably act – raising the price of some forms of travel; working to influence attitudes to travel, developing "urban niches" for particular areas in terms of improving their potential as public transport hubs.

There appears to be much scope for furthering our research in these areas – assessing the issues of context and segmentation within the packaging of different socio-economic, cultural and land use variables – to understand more fully what combinations of the wide range of options are likely to work best in reducing energy consumption in travel.

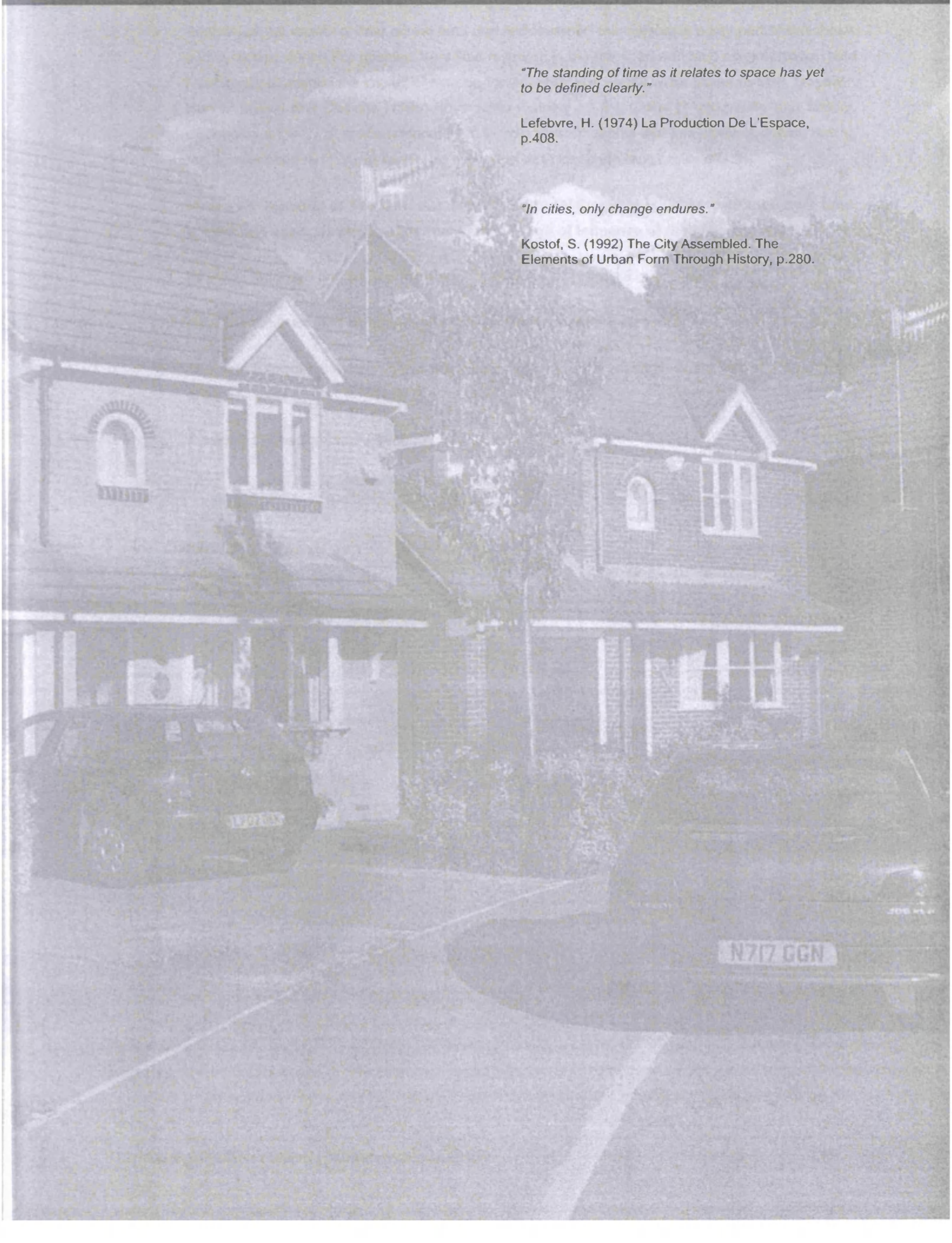
06. The Temporal Effect: A More Detailed Analysis

"The standing of time as it relates to space has yet to be defined clearly."

Lefebvre, H. (1974) La Production De L'Espace, p.408.

"In cities, only change endures."

Kostof, S. (1992) The City Assembled. The Elements of Urban Form Through History, p.280.



6. The Temporal Effect: A More Detailed Analysis

Analysis of the impact of time on the land use and transport relationship is a key part of this thesis and is tackled during this chapter. Very little research in the transport and land use interaction field has directly examined the impact of time on travel behaviour. In the wider literature field, however, Harvey (2000) and Castells (1998) have written widely on the nexus of geography and history, developing a theory of spatio-temporality. It is from these thoughts that inspiration is drawn: testing the Surrey urban form, socio-economic and travel data for spatio-temporality effects.

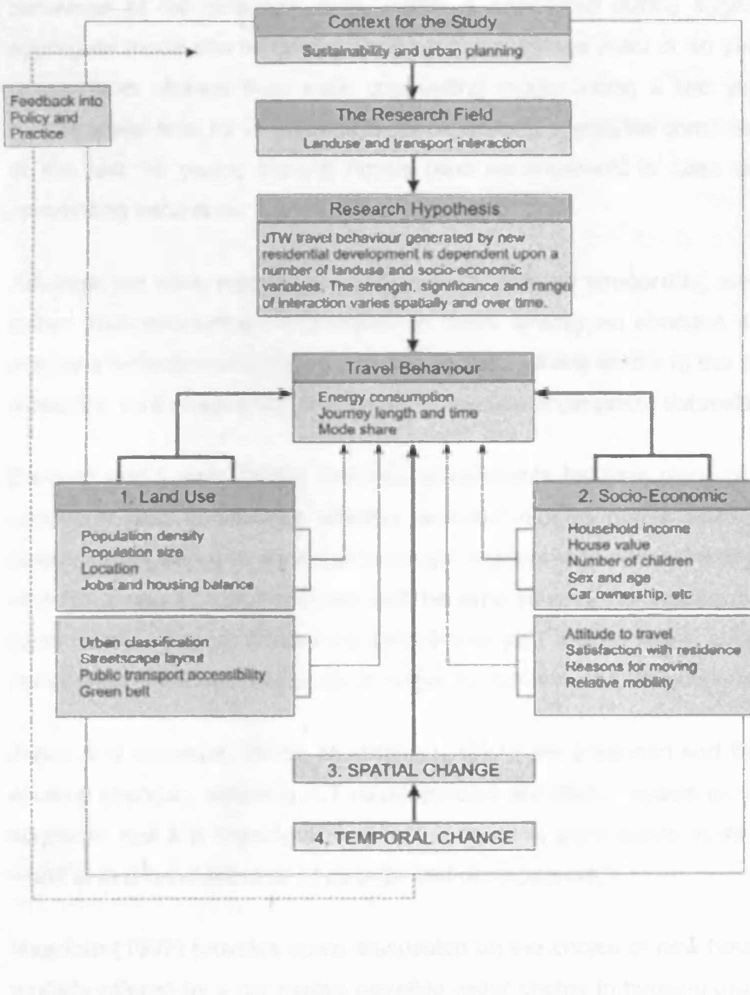
Research Question 5: The land use and transport relationship is likely to change over time. What is the scale, strength, significance and range of influence of the temporal effect?

H_0 – The land use and transport relationship does not change over time.

H_1 – The land use and transport relationship does change over time.

The key diagram below shows the relation of this part of the research to the rest of the empirical analysis.

Figure 6.1: *The Temporal Effect*



6.1 Spatio-Temporality

Within the specific land use and transport interaction literature, Gordon and Richardson (1989, 1991 and 1997) are perhaps the most interesting in terms of considering the temporal angle. They *speculate* that co-location may occur in low-density suburban areas; whereby firms and households periodically re-adjust spatially to achieve balanced average commuting distances and duration. However there is little empirical evidence behind this argument; and no systematic tracking of individual household travel behaviour over time. Much of the other research – Newman and Kenworthy (1989) et al – is based on one "snapshot" in time, with analysis confined to one year's data, and little thought given to changing trends over time.

Empirically there can be difficulties in analysing temporal change. Dargay and Hanly have carried out a series of analyses using the British Household Panel Survey (BHPS), including the consideration of car ownership (2000) and commuting and time (2003). The BHPS is a 5,000 household survey, a stratified sample representative of all households in Britain. Dargay and Hanly (2003) describe the problem of attrition, which is evident in many repeat panel surveys, either due to non-response, unusable response or where households/individuals cannot be contacted. The BHPS has a relatively low attrition rate – 60% of those interviewed in the original 1991 survey remain in the survey in 2000. In terms of findings, Dargay and Hanly describe the volatility of travel behaviour at the individual level, which is concealed during aggregate analysis. For example, aggregate mode shares only change by a percentage point or so year on year, but nearly 20% of respondents change their main commuting mode during a two year period. 26% increase or reduce travel time by 10 minutes or more, despite aggregate commute time remaining almost static in the last 10 years. Moving house (and employment) is seen as having a major impact on commuting behaviour.

Amongst the wider researchers who have considered temporality, most have done this tangentially, rather than structuring the analyses to focus directly on changes over time. In many cases this maybe a reflection of a lack of data availability – there is little in the way of time-series data readily available, so a major effort is required to develop appropriate datasets.

Cervero and Landis (1992) stratified respondents by their place of residence at the time of job relocation and considered whether workers moved house after this relocation. Commuting distances appeared to decrease amongst workers who were already living in the suburbs. Those who remained in San Francisco and became reverse commuters saw their travel distances rise enormously. Former central city inhabitants who moved to the suburbs were better off, but their commuting distances tended to be longer than before the relocation of both job and home.

Jones and Salomon (1992); Mokhtarian (1991); and Hickman and Banister (2005c) consider likely societal changes, including ICT developments and likely impacts on travel. Jones (1983 and 1991) suggests that it is important to reflect a dynamic perspective in studies of travel behaviour: "the world is in a constant state of change and development."

Headicar (1997) provides some discussion on the choice of new housing in the UK. The improved mobility offered by a car makes possible wider choice in housing location, in effect 'buying' greater locational choice by undertaking longer journey distances (though not usually longer travel times). Headicar notes that the causation may be the other way round: the loss of local employment or difficulty in moving house at the time of a job move forces people to acquire or use a car over longer distances in order to maintain the desired activity links - hence there is some temporal effect.

It is possibly surprising that temporal change has not been analysed more in the literature - intuitively travel behaviour is likely to change over time as people adapt their lifestyles to their new residential locations. The Surrey dataset allows consideration of this - with travel behaviour systematically tracked over time from the same households.

The significance of in-migration should not be under-estimated. In Headicar's research in Oxfordshire, there is a pronounced difference in the behaviour of otherwise similar people: between those who have previously lived in the same town and those who move into it. For example, Banbury (one of the towns in Oxfordshire located along the M40) has traditionally been promoted for expansion by the local planning authorities because it has a strong base of local jobs and facilities and is geographically distant from other urban centres. New development has attracted more people from outside the town than from the town itself. Some years after their house move, these people are much more likely (by a factor of 2.6) to work outside the town. Inevitably these involve long - or very long journeys - and almost all by car (Note the previous discussion in Chapter 4 on resident location adjacent to the strategic highway network).

It is possible that the high car use evident in places with good car accessibility is simply due to the fact that they attract people who are pre-disposed to car intensive behaviour. This was tested by looking at mode and length of journey to work before and after the house move. There was a net shift of 18% towards less sustainable forms of travel amongst people moving to developments close to the city (i.e. to car from non-car, or to longer distance categories of car journey). However there was a still greater shift (26%) amongst people moving to developments in the free-standing towns.

Spence and Frost (1995) carried out research along similar lines, finding that the journey to work was influenced by a complex set of processes; including employment opportunities, migration and infrastructure (comprising urban form and the pricing structures for its use). Critically they also comment that those moving out of central London into the suburbs in the south-east fit into a particular socio-economic and age profile, i.e. the stage of life when ready to start a family.

This is confirmed by detailed analysis from Fielding (1993) on migration patterns in the South East. Spence et al go on to suggest that within 10 years, the majority of these outward migrants have found employment local to their new location. Thus outward location does not necessarily mean increased trip lengths in the long term. Generally, however, the impact of time on travel patterns is under-researched, i.e. few researchers have asked what happens a few years after moving home, do some people travelling long distances to work eventually gain employment nearer to home?

A related issue from research almost 50 years ago: classical economist Tiebout (1956) introduced the concept of urban area niche, suggesting that municipalities within an urban area would specialise to attract residents. Each locality would attempt to carve out its own market niche.

Under extreme assumptions, this cross-municipality competition would meet the various demands of consumers for different types of neighbourhoods with different levels of local public services.

So, in summary, there has been little research which systematically tracks travel behaviour of households over time. This thesis considers the impact of time by using data from 1998 and 2001. The key issues are:

- What temporal changes are evident? What individual volatility is evident?
- What difference does type of resident make (in terms of, say, people who stay in the area compared to out-movers and in-movers?) In particular do in-migrators have markedly different travel patterns to existing residents?
- How can the attrition problem be controlled for?
- Does the land use and travel behaviour relationship, in particular, change over time?
- Does co-location of residences and employment occur over time in Surrey? Do journey to work trips migrate towards a "natural balance: of distance and duration?
    - Which groups are most affected? Those who live in the suburbs? Do urban residents exploit their greater workplace locational choice with longer commutes?
- Does Tiebout competition lead to an efficient supply of desired neighbourhood types? Why do particular locations attract a particular type of travel user? Do inaccessible locations constrain mobile people who move there or only attract immobile people (and vice versa: do accessible locations attract mobile people?). As a consequence of a move, do people adopt a particular travel pattern? Are certain types of neighbourhood under-supplied?

EVIDENCE FROM SURREY: THE TEMPORAL EFFECT AND TRAVEL BEHAVIOUR

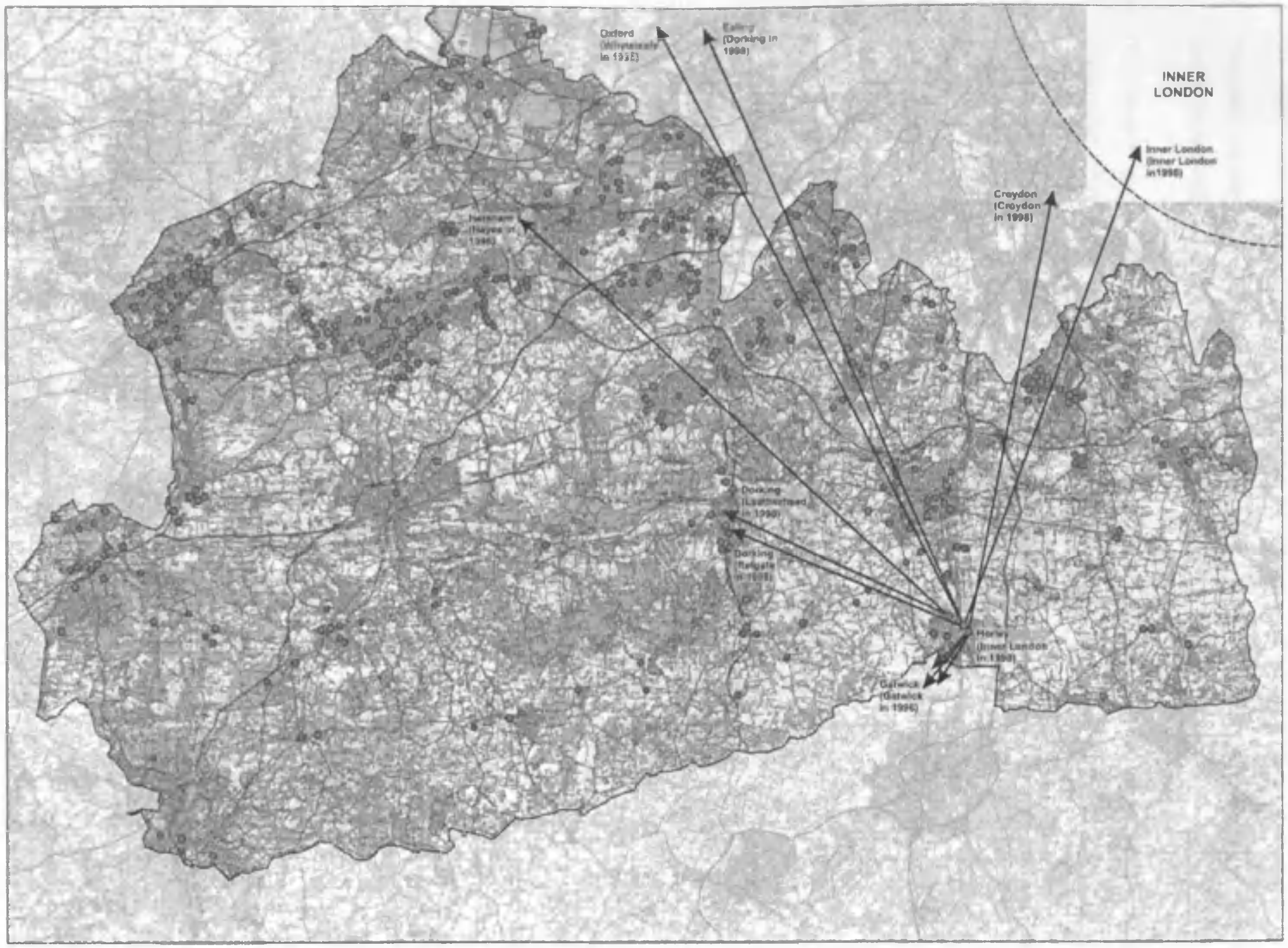
6.2 Individual Volatility

Figure 6.2 shows the locations of new household residences and workplaces in 1998 in Surrey and the change in workplace by 2001 - just for the new housing development in north Horley (also considered earlier in Chapter 4 (Figure 4.34 and associated commentary). We can see that the changes over time are incredibly complex. Some commutes become longer, some shorter, others stay the same distance. Some change modes, others remain the same mode. The individual volatility is huge – a real "travel kurtosis effect" – but this is hidden by aggregate analysis.

The example shown clearly illustrates the importance of change over time. Commutes to London, Croydon and Gatwick in 1998 remain the same in 2001. Others change - a former London commute in 1998 modifies to a local commute to Horley in 2001. Some of the changes are unexpected - a Dorking commute in 1998 modifies to Ealing in 2001, a Whytleafe commute in 1998 modifies to Oxford in 2001. Clearly these latter two changes are facilitated by M25 access.

Hence we can see how the pattern of commuting in Surrey has become more complex - even over a short timespan of 3 years - the radial commute into the key towns or London is no longer the dominant form. Unfortunately, the public transport network in Surrey, particularly by rail, remains radial in nature. This no longer serves as an option for many people. In addition, people periodically change their travel patterns - with both workplace and home location changes - facilitated by a road network which allows access to a wide area. Hence car dependency becomes more and more entrenched in people's modern lifestyles.

Figure 6.2: *Residence and Workplace Location Change in Surrey*



6.3 Effects by Type of Resident

The use of two surveys (in 1998 and 2001) allows us to track and analyse the impact of time on travel behaviour. A useful disaggregation is to consider the different travel behaviour patterns of the "stayers", "outmovers" and "inmovers". Cervero, Headicar and others, remember, have previously inferred that inmovers are likely to have different travel behaviour patterns to existing residents.

The typology is defined as follows:

- 'Stayers': people who occupied a new household in September 1998 and who still lived in the same household in September 2001
- 'Outmovers': people who occupied a new household in September 1998, but moved out before September 2001
- 'Inmovers': people who lived elsewhere in September 1998, but moved into a new household before September 2001

Figures 6.3 shows the three different groupings in the new household occupier dataset.

Figure 6.3: *Stayers, Outmovers and Inmovers in Surrey*

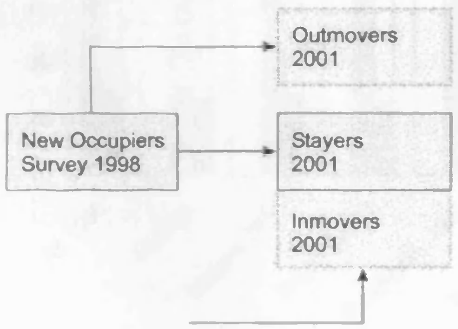
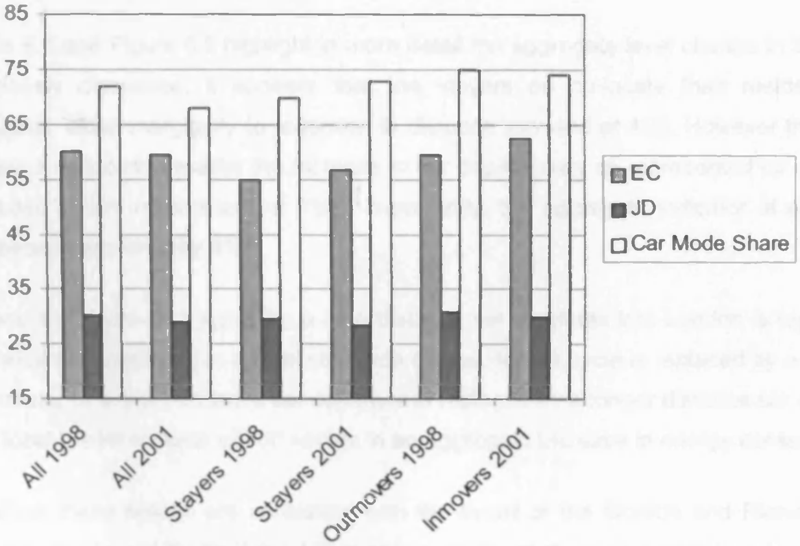


Table 6.1 and Figure 6.4 illustrates how energy consumption, journey distance and journey time varies by resident type.

Table 6.1: *Energy Consumption, Journey Distance and Journey Time by Resident Typology*

Resident Typology	Energy Consumption (MJ/JTW)	Journey Distance (Km)	Journey Time (Mins)	Car Mode Share (%)
All 1998	60.1	30.1	41.9	72
All 2001	59.4	29.0	41.4	68
Stayers 1998	54.9	29.5	40.5	70
Stayers 2001	56.8	28.4	39.9	73
Outmovers 1998	59.4	30.7	41.0	75
Inmovers 2001	62.6	29.8	39.3	74

Figure 6.4: *Energy Consumption, Journey Distance and Journey Time by Resident Typology*



As we can see, there are a number of important trends:

- The stayers: are the least energy consuming of the cohorts. However, energy consumption increases over time, by 4% from 1998-2001. This reflects trends which move in different directions - journey distance and journey time reduces by 4%, yet car mode share increases by 3%;

- The outmovers: represent the most mobile grouping in terms of journey distance travelled (4% greater distance than the stayers in 1998) have the highest car mode share (at 75%), and account for 8% more in energy consumption than the stayers in 1998;

- The inmovers: are more mobile than the stayers, but less mobile than the outmovers. They account for the greatest in energy consumption, 10% more than the stayers in 2001 (the difference in energy consumption between inmovers and outmovers is accounted for by the walk/cycle/public transport mode share more than the car mode share).

These findings are particularly important - travel behaviour varies markedly by resident type, and the change over time does too. The location of new households, and the modelling of likely future travel behaviour, should recognise this likely difference in segmentation.

6.4 Aggregate Level Analysis of the "Stayers" Data

The potential difficulty with attrition in analysing temporal change is removed by considering the stayers data only – so individual responses to both the 1998 and 2001 survey. Any changes in travel are therefore attributable to changes over time rather than attritional effects.

Note that spatially the individual volatility is difficult to interpret with aggregate level analysis. A 'spiders web' version of Figure 6.2 for the complete Surrey dataset would be unreadable. Hence, aggregate level change remains important - numerically it is slightly easier to see what changes are occurring over time.

Table 6.2 and Figure 6.5 highlight in more detail the aggregate level change in the Surrey data. As previously discussed, it appears that the stayers do co-locate their resident and workplace locations, albeit marginally (a reduction in distance travelled of 4%). However the focus on journey distance co-location masks the increase in car dependency as represented by car mode share (an increase in car mode share of 3%). Importantly, the aggregate indicator of energy consumption increases over time (by 4%).

Hence it appears that, typically, a long distance rail commute into London is replaced by a shorter distance car commute; or a local commute by bus, foot or cycle is replaced by a longer distance car commute; or a short distance car commute is replaced by a longer distance car commute. Critically this local "travel kurtosis effect" results in an aggregate increase in energy consumption.

In effect these results are consistent with the thrust of the Gordon and Richardson distance co-location thesis, yet by itself this offers only a partial analysis of a complex picture – the aggregate increase in energy consumption is the important figure in sustainability terms.

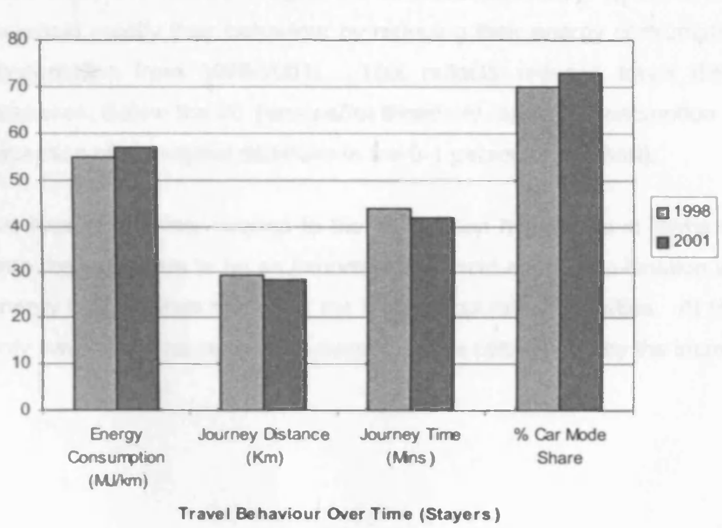
Table 6.2 *Changing Travel Behaviour Over Time in Surrey - Stayers*

Changing Travel Behaviour	Count		Average of Energy Consumption (MJ/jtw)			Average of Journey to Work Distance (Km)		
	1998	2001	1998	2001	% Change	1998	2001	% Change
Total	376	376	54.9	56.8	3.5%	29.5	28.4	-3.7%

Average of Journey to Work Time (Mins)			Car Mode Share		
1998	2001	% Change	1998	2001	% Change
43.8	41.9	-4.2%	70%	73%	+3%

Data: Surrey New Occupiers Survey 1998 and 2001. Stayers data only.

Figure 6.5: *Changing Travel Behaviour Over Time in Surrey*



6.5 Detailed Analysis of the "Stayers" Data

More detailed, disaggregated analysis of the data is useful and this is given below in terms of the impact of time on the land use and travel behaviour relationship.

Residential Population Density

Broadly we might expect that, as the density of development increases, average energy consumption and journey distance decreases for any given year – the "snapshot" in time analysis. However from the previous literature we do not know how this density and travel relationship develops over time.

The 'stayers' data broadly supports this expected trend. There is an inverse linear relationship between density and travel – as density increases travel reduces in energy consumption - with the exception of the 20-35 persons/ha cohort which has a higher than expected energy consumption pattern.

Over time, the density ranges are affected differently: households over the 20-35 persons/ha threshold modify their behaviour by reducing their energy consumption (a 7% reduction in energy consumption from 1998-2001). This reflects reduced travel distance; car mode share still increases. Below the 20 persons/ha threshold, energy consumption increases over time (with the exception of a marginal decrease in the 0-1 persons/ha cohort).

So there is a further nuance to the co-location hypothesis in terms of density – within the Surrey data there appears to be an important threshold effect. Co-location in terms of travel distance *and* energy consumption occurs at the higher population densities. At the lower population densities, only travel distance co-location occurs, and is outweighed by the increase in energy consumption.

Table 6.3: *The Stayers – Population Density and Energy Consumption*

Residential Population Density (Persons/ha)	Travel Behaviour	1998	2001	% Change	Count
0-1	EC	71.0	69.8	-2%	16
	JD	33.0	32.9	0%	
	Car Mode Share (%)	81%	88%	7%	
1-10	EC	59.9	64.4	8%	153
	JD	30.3	29.6	-2%	
	Car Mode Share (%)	73%	76%	3%	
10-20	EC	45.2	49.5	9%	107
	JD	28.3	28.6	1%	
	Car Mode Share (%)	61%	63%	2%	
20-35	EC	60.6	56.2	-7%	74
	JD	29.4	25.2	-14%	
	Car Mode Share (%)	76%	78%	2%	
>35	EC	37.8	34.9	-8%	26
	JD	27.5	26.4	-4%	
	Car Mode Share (%)	65%	69%	4%	
Grand Total Energy Consumption		54.9	56.8	3%	376
Grand Total Journey Distance		29.5	28.4	-4%	
Grand Total Car Mode Share (%)		70%	73%	3%	

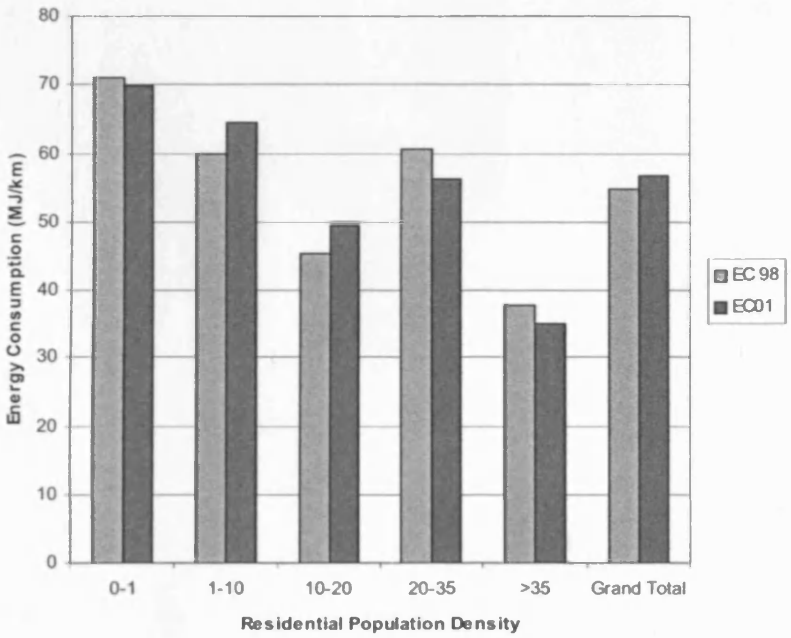
Data: Surrey New Occupiers Survey 1998 and 2001. Stayers data only.

Shading Key

X: 5% > sample average

Y: 5% < sample average

Figure 6.6: *The Stayers – Population Density and Energy Consumption*



Residential Population Size

As we have seen previously, household location according to settlement size can also be a key determinant of the patterns of travel. In the UK, broadly, we find that the larger the population size, the shorter the trips - with the exception of urban areas sized between 25-50,000 - which also show lower travel distances and energy consumption. This is reflected in the stayers data, where the households found in the rural locations are the highest energy consumers, combining a lengthy average travel distance with a high car mode share. Households in the 7 key towns have a lengthier average journey distance, but a low car mode share (reflecting the many commutes into London).

Over time households in the rural locations increase their average journey length and car mode share, meaning that average energy consumption increases by 11%. Only the households in the smaller towns in Surrey reduce their energy consumption over time.

Table 6.4: *The Stayers – Population Size and Energy Consumption*

Residential Population Size	Travel Behaviour	1998	2001	% Change	Count
7 Key Towns	EC	52.5	54.2	3%	70
	JD	32.5	32.5	0%	
	Car Mode Share (%)	54%	60%	6%	
Other 33 Towns	EC	53.1	50.4	-5%	153
	JD	28.1	25.2	-10%	
	Car Mode Share (%)	73%	73%	0%	
Other Rural	EC	57.7	64.1	11%	153
	JD	29.3	29.6	1%	
	Car Mode Share (%)	74%	79%	5%	
Grand Total Energy Consumption		54.9	56.8	3%	376
Grand Total Journey Distance		29.5	28.4	-4%	
Grand Total Car Mode Share (%)		70%	73%	3%	

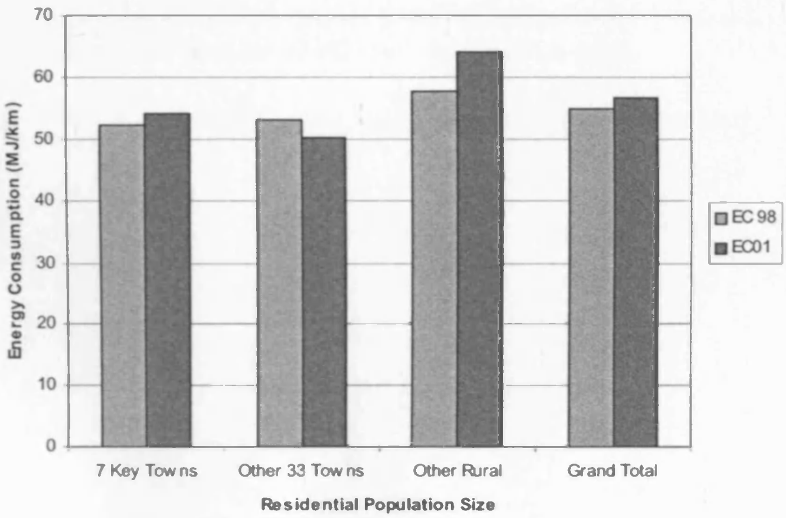
Data: Surrey New Occupiers Survey 1998 and 2001. Stayers data only.

Shading Key

X: 5% > sample average

Y: 5% < sample average

Figure 6.7: *The Stayers – Population Size and Energy Consumption*



Distance from London

We would expect that energy consumption would rise with increasing distance from London and this is very well reflected in the stayers data, with a strong linear relationship involving increasingly lengthy average travel distance and high car mode shares.

Over time almost all the distance from London cohorts increase their energy consumption. The clearest trend is perhaps that households furthest from London increase their car mode share to the greatest extent.

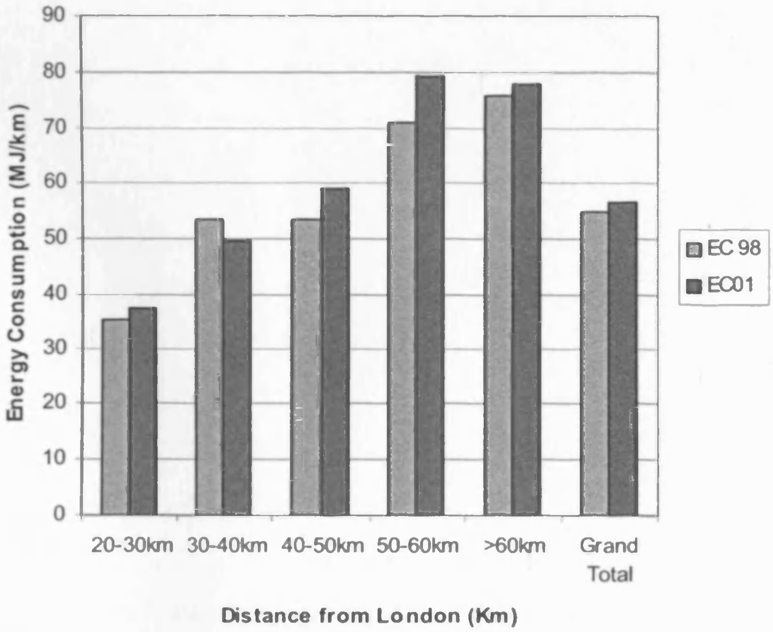
Table 6.5: *The Stayers – Distance from London and Energy Consumption*

Distance from London	Travel Behaviour	1998	2001	% Change	Count
20-30km	EC	35.1	37.6	7%	53
	JD	22.2	22.2	0%	
	Car Mode Share (%)	64%	58%	-6%	
30-40km	EC	53.6	49.7	-7%	134
	JD	30.4	27.9	-8%	
	Car Mode Share (%)	66%	67%	1%	
40-50km	EC	53.4	58.9	10%	113
	JD	28.8	27.7	-4%	
	Car Mode Share (%)	73%	79%	6%	
50-60km	EC	71.0	79.3	12%	38
	JD	38.4	35.0	-9%	
	Car Mode Share (%)	76%	87%	11%	
>60km	EC	75.8	77.9	3%	38
	JD	29.8	34.6	16%	
	Car Mode Share (%)	76%	82%	6%	
Grand Total Energy Consumption		54.9	56.8	3%	376
Grand Total Journey Distance		29.5	28.4	-4%	
Grand Total Car Mode Share (%)		70%	73%	3%	

Data: Surrey New Occupiers Survey 1998 and 2001. Stayers data only.

Shading Key
X: 5% > sample average
Y: 5% < sample average

Figure 6.8: *The Stayers – Distance from London and Energy Consumption*



Distance from Strategic Road Network

The previous Surrey analysis has shown that energy consumption rises with households located close to the strategic highway network (within 3km), particularly the M3 and A31. This is again well reflected in the stayers data, with locations close to both routes being associated with long travel distances, and the A31, in particular, high car mode shares.

Over time households close to the M3, A31 and A3 increase their energy consumption markedly, a reflection of higher car mode shares and/or longer travel distances. Households located near to the A31 consume 58% more energy than those located more than 3km from the strategic road network in 2001.

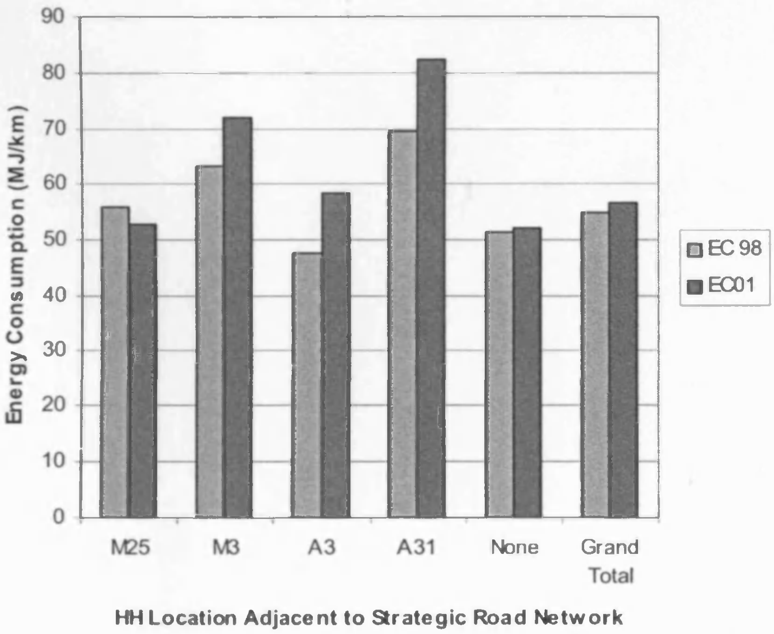
Table 6.6: *The Stayers – Distance from Strategic Road Network and Energy Consumption*

Distance from Road Network	Travel Behaviour	1998	2001	% Change	Count
M25	EC	55.8	52.8	-5%	99
	JD	30.3	27.5	-9%	
	Car Mode Share (%)	71%	71%	-	
M3	EC	63.4	72.0	14%	26
	JD	32.8	27.0	-18%	
	Car Mode Share (%)	69%	81%	12%	
A3	EC	47.8	58.4	22%	25
	JD	23.2	25.6	10%	
	Car Mode Share (%)	76%	72%	-4%	
A31	EC	69.5	82.2	18%	34
	JD	36.9	40.5	10%	
	Car Mode Share (%)	82%	82%	-	
None	EC	51.6	52.1	1%	192
	JD	28.2	27.3	-3%	
	Car Mode Share (%)	67%	71%	4%	
Grand Total Energy Consumption		54.9	56.8	3%	376
Grand Total Journey Distance		29.5	28.4	-4%	
Grand Total Car Mode Share (%)		70%	73%	3%	

Shading Key
X: 5% > sample average
Y: 5% < sample average

Data: Surrey New Occupiers Survey 1998 and 2001. Stayers data only.

Figure 6.9: *The Stayers – Distance from Strategic Road Network and Energy Consumption*



Jobs-Housing Balance

The stayers data again reflects the complete Surrey dataset in that the more balanced jobs-housing ratios (the 1.25-1.50 jobs-house cohort) are associated with the shortest average travel distances and, in 1998 at least, the lowest car mode shares.

Over time households in all the jobs-housing cohorts reduce their average journey lengths, however car mode shares also increase for all. This means that the composite average energy consumption also increases for most cohorts (including the most balanced). The 1.25-1.50 jobs-house cohort however remains 13% less energy consuming than the sample average in 2001, mainly a result of a much shorter average journey distance, but also a lower car mode share.

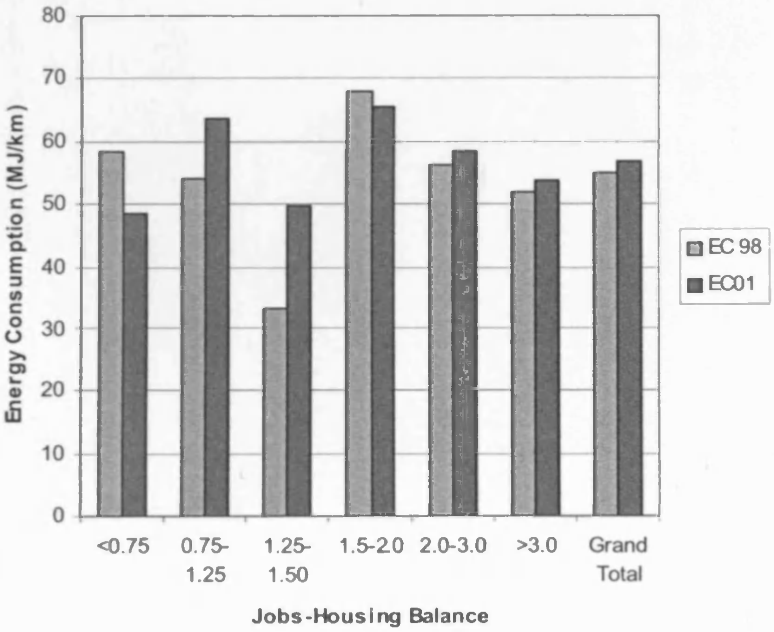
Table 6.7: *The Stayers – Jobs-Housing Balance and Energy Consumption*

Jobs-Housing Balance	Travel Behaviour	1998	2001	% Change	Count
<0.75	EC	58.4	48.6	-17%	44
	JD	28.2	25.2	-11%	
	Car Mode Share (%)	61%	66%	5%	
0.75-1.25	EC	54.0	63.5	18%	63
	JD	29.9	28.6	-4%	
	Car Mode Share (%)	65%	73%	8%	
1.25-1.50	EC	33.3	49.6	49%	10
	JD	23.6	18.8	-20%	
	Car Mode Share (%)	50%	70%	20%	
1.50-2.0	EC	67.9	65.4	-4%	31
	JD	35.1	34.9	-1%	
	Car Mode Share (%)	71%	74%	3%	
2.0-3.0	EC	56.2	58.5	4%	88
	JD	27.1	25.9	-4%	
	Car Mode Share (%)	76%	82%	7%	
Grand Total Energy Consumption		54.9	56.8	3%	376
Grand Total Journey Distance		29.5	28.4	-4%	
Grand Total Car Mode Share (%)		70%	73%	3%	

Data: Surrey New Occupiers Survey 1998 and 2001. Stayers data only.

Shading Key
X: 5% > sample average
X: 5% < sample average

Figure 6.10: *The Stayers – Jobs-Housing Balance and Energy Consumption*



Strategic Urban Classification

We would expect that the stayers data would reflect the findings of the complete Surrey sample in that energy consumption would be least in town centre locations, rising in the rest of urban area locations, and be highest in rural locations. This is the case. Households in rural locations consume 25% more energy than the stayers sample average in 1998 – but this refelcts an increased car dependency rather than increased journey length (remember households in town centre locations, in places such as Woking, Guildford or Epsom, are very well placed for commuting lengthy distances into London).

Over time households in all the urban classifications (town centre, rest of urban area and rural) reduce their average journey length, however car mode share increases in all. This means that composite energy consumption increases (with the exception of the rural locations which remain at a similar level of energy consumption).

Table 6.8: *The Stayers – Urban Classification and Energy Consumption*

Urban Classification	Travel Behaviour	1998	2001	% Change	Count
Town Centre	EC	41.4	46.5	12%	43
	JD	30.7	29.1	-5%	
	Car Mode Share (%)	53%	56%	3%	
Rest of Urban Area	EC	52.3	54.3	4%	248
	JD	28.8	27.8	-4%	
	Car Mode Share (%)	71%	73%	2%	
Rural	EC	68.9	68.8	0%	85
	JD	30.9	29.7	-4%	
	Car Mode Share (%)	74%	81%	7%	
Grand Total Energy Consumption		54.9	56.8	3%	376
Grand Total Journey Distance		29.5	28.4	-4%	
Grand Total Car Mode Share (%)		70%	73%	3%	

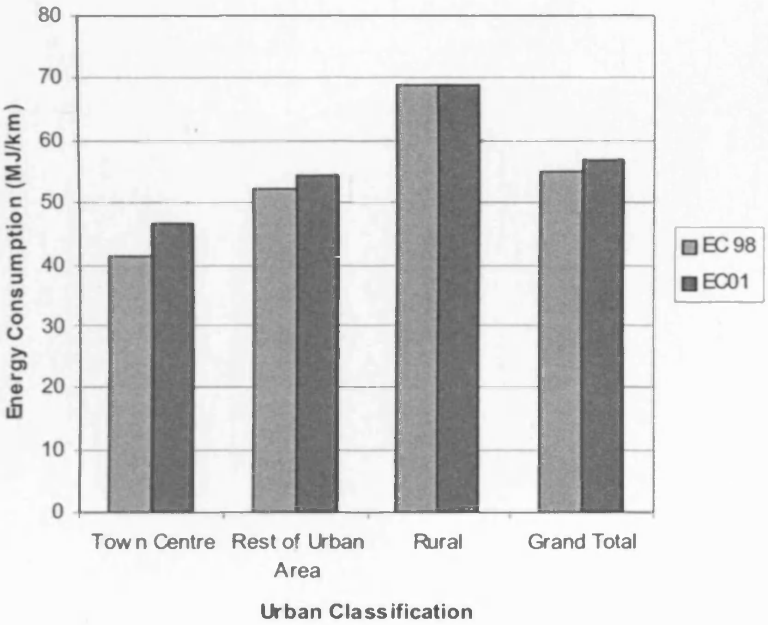
Data: Surrey New Occupiers Survey 1998 and 2001. Stayers data only.

Shading Key

X: 5% > sample average

Y: 5% < sample average

Figure 6.11: *The Stayers – Urban Classification and Energy Consumption*



Neighbourhood Streetscape Layout

The 1998 stayers data highlights that energy consumption is lowest in households located on the neo-traditional grid style street networks, and rises in the households located on local and remote cul-de-sacs. The 2001 stayers data broadly supports this – remote cul-de-sacs certainly remaining much higher (11% higher) in energy consumption than the neo-traditional grid networks. These trends reflect an increased average journey distance from households located on cul-de-sac style street networks.

Over time the trends aren't particularly clear, however households located on remote cul-de-sacs increase their energy consumption by 3%, reflecting increased car dependence. .

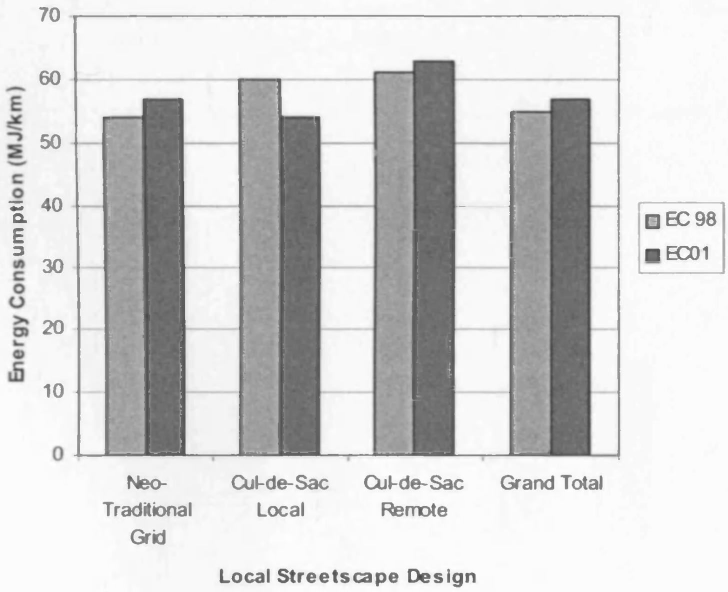
Table 6.9: *The Stayers – Neighbourhood Streetscape Layout and Energy Consumption*

Neighbourhood Streetscape Design	Travel Behaviour	1998	2001	% Change	Count
Neo-Traditional Grid	EC	54.0	56.8	5%	273
	JD	27.9	27.5	-1%	
	Car Mode Share (%)	70%	72%	2%	
Cul-de-Sac Local	EC	59.9	53.9	-10%	70
	JD	32.8	29.0	-12%	
	Car Mode Share (%)	69%	74%	5%	
Cul-de-Sac Remote	EC	61.2	62.9	3%	33
	JD	35.2	34.1	-3%	
	Car Mode Share (%)	70%	76%	6%	
Grand Total Energy Consumption		54.9	56.8	3%	376
Grand Total Journey Distance		29.5	28.4	-4%	
Grand Total Car Mode Share (%)		70%	73%	3%	

Shading Key
X: 5% > sample average
Y: 5% < sample average

Data: Surrey New Occupiers Survey 1998 and 2001. Stayers data only.

Figure 6.12: *The Stayers – Neighbourhood Streetscape Layout and Energy Consumption*



Public Transport Accessibility

The public transport accessibility and travel disagregation shows quite clear trends. The stayers data supports the argument that energy consumption rises as public transport accessibility to the town centres in Surrey reduces. This reflects mainly an increasingly lengthy average travel distance, and also, to a certain extent, higher car mode shares.

The trends over time are also apparently clear - households in locations with good public transport accessibility (0-20 minutes journey time to the town centres in Surrey) reduce their average journey length, meaning that average energy consumption reduces by 2-4% from 1998-2001. Conversely, households in locations with poor public transport accessibility (>20 minutes journey time to the town centres in Surrey) increase their average journey length and/or their car mode share, meaning that average energy consumption increases by 6-9%.

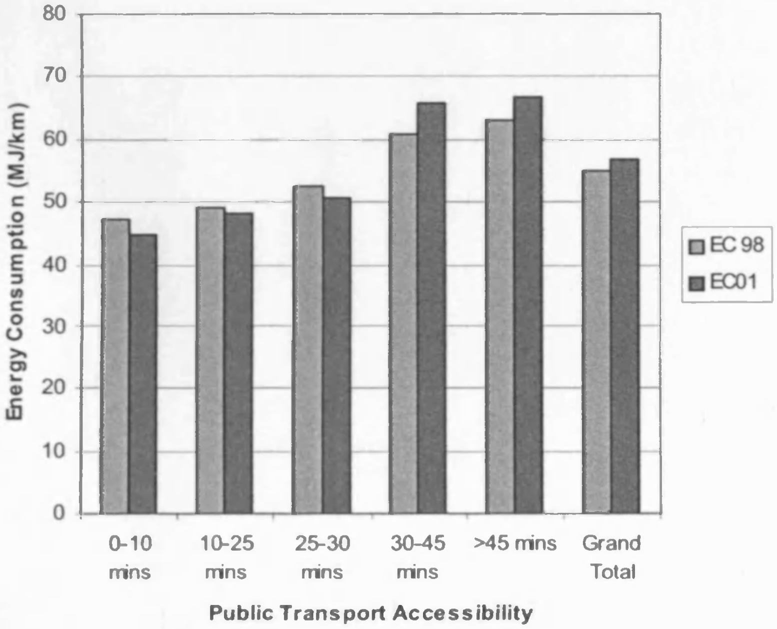
Table 6.10: *The Stayers – Public Transport Accessibility and Energy Consumption*

Public Transport Accessibility	Travel Behaviour	1998	2001	% Change	Count
0-10 mins	EC	47.3	44.9	-5%	67
	JD	26.8	23.8	-11%	
	Car Mode Share (%)	63%	66%	3%	
10-25 mins	EC	49.0	48.1	-2%	77
	JD	27.3	25.4	-7%	
	Car Mode Share (%)	74%	74%	-	
25-30 mins	EC	52.4	50.5	-4%	51
	JD	26.3	24.2	-8%	
	Car Mode Share (%)	67%	73%	6%	
30-45 mins	EC	60.7	65.9	9%	84
	JD	34.6	33.3	-4%	
	Car Mode Share (%)	68%	71%	3%	
>45 mins	EC	63.1	66.8	6%	86
	JD	30.7	32.5	6%	
	Car Mode Share (%)	77%	80%	3%	
Grand Total Energy Consumption		54.9	56.8	3%	376
Grand Total Journey Distance		29.5	28.4	-4%	
Grand Total Car Mode Share (%)		70%	73%	3%	

Data: Surrey New Occupiers Survey 1998 and 2001. Stayers data only.

Shading Key
X: 5% > sample average
Y: 5% < sample average

Figure 6.13: *The Stayers – Public Transport Accessibility and Energy Consumption*



Resident Location (Relative to the Green Belt)

The resident location (relative to the green belt) and travel disagregation also shows clear trends. As might be expected, the stayers data supports the argument that energy consumption is lowest for households located within the urban area, and rises for those located in the Green Belt (22% than the sample average in 1998) and still further for those located in countryside beyond the Green Belt (25% than the sample average in 1998). This reflects higher car mode shares and, for households located in countryside beyond the Green Belt, much lengthier average travel distances.

The trends over time are also apparently clear - households located in countryside beyond the Green Belt increase their energy consumption most over time – by 19%. Households located elsewhere increase their energy consumption by 3%.

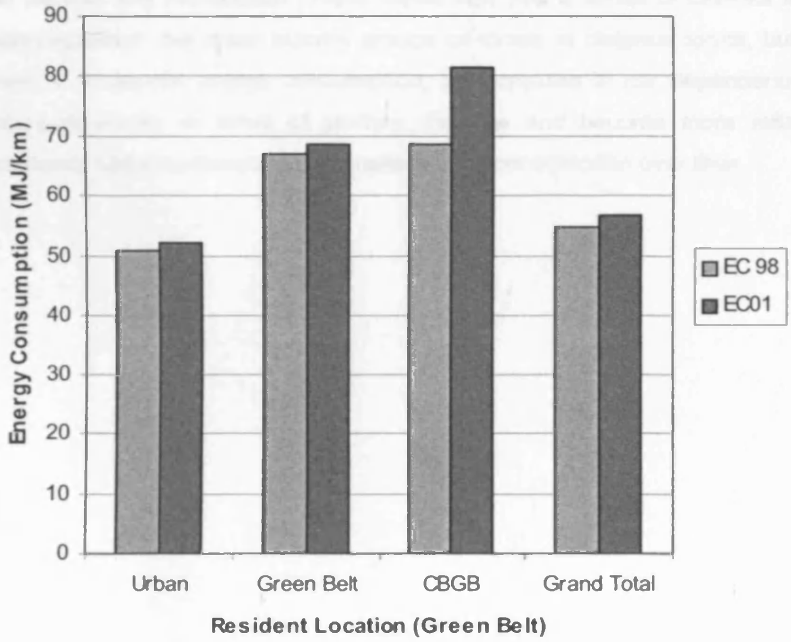
Table 6.11: *The Stayers – Resident Location (Green Belt) and Energy Consumption*

Resident Location Relative to the Green Belt	Travel Behaviour	1998	2001	% Change	Count
Urban	EC	51.0	52.3	3%	288
	JD	28.9	27.7	-4%	
	Car Mode Share (%)	68%	69%	1%	
Green Belt	EC	66.9	68.7	3%	73
	JD	28.4	28.1	-1%	
	Car Mode Share (%)	75%	84%	9%	
Countryside Beyond the Green Belt	EC	68.8	81.5	19%	15
	JD	46.6	42.5	-9%	
	Car Mode Share (%)	80%	87%	7%	
Grand Total Energy Consumption		54.9	56.8	3%	376
Grand Total Journey Distance		29.5	28.4	-4%	
Grand Total Car Mode Share (%)		70%	73%	3%	

Shading Key
X: 5% > sample average
X: 5% < sample average

Data: Surrey New Occupiers Survey 1998 and 2001. Stayers data only.

Figure 6.14: *The Stayers – Resident Location (Green Belt) and Energy Consumption*



Household income

Considering the impact of income on travel co-location effects within the stayers data is also very instructive. Energy consumption rises with increasing household income; the >£100k household income cohort, for example, consuming 22% higher energy in their commutes to work in 1998. This reflects much higher average travel distance, but, importantly, not higher car mode shares. It is the lower household income groups (<£35k) that are more car dependent. This reflects the peculiarities of the Surrey location – with a high dependence on commuting into London by rail for higher income jobs.

Over time all income groups increase their energy consumption. However, within this, there are a number of countervailing trends. The lower household income groups (<£100k) appear to co-locate homes and workplaces and reduce their commute distance, yet they increase their car mode share. In composite terms, energy consumption rises marginally (by up to 2%).

It is the highest earners (>£100k household incomes) that increase both their average journey distances and car mode shares; and hence their composite energy consumption to a large degree: an increase of 27% from 1998-2001. So an intuitive story, and a further nuance to the co-location [and dis-location] debate.

The Gordon and Richardson (1989) thesis thus has a series of caveats to it in terms of income disaggregations: the lower income groups co-locate in distance terms, but this is outweighed, in terms of composite energy consumption, by increases in car dependency. The higher income groups dis-locate in terms of journey distance *and* become more reliant on the car, hence experience large increases in composite energy consumption over time.

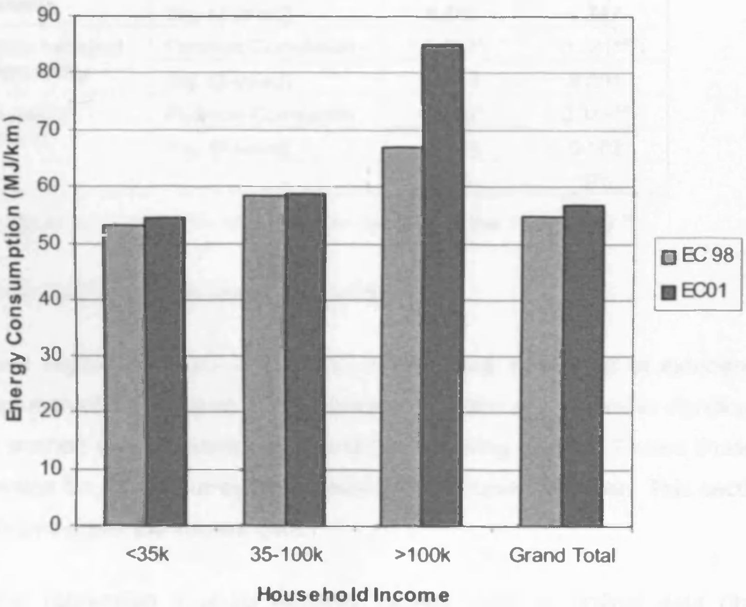
Table 6.12: *The Stayers – Household Income and Energy Consumption*

Household Income	Travel Behaviour	1998	2001	% Change	Count
<£35k	EC	53.4	54.5	2%	54
	JD	22.2	21.8	-2%	
	Car Mode Share (%)	78%	83%	5%	
£35-100kl	EC	58.5	58.7	0%	200
	JD	31.7	30.0	-5%	
	Car Mode Share (%)	70%	73%	3%	
>£100k	EC	67.1	85.0	27%	34
	JD	42.9	46.2	8%	
	Car Mode Share (%)	56%	65%	9%	
Grand Total Energy Consumption		54.9	56.8	3%	376
Grand Total Journey Distance		29.5	28.4	-4%	
Grand Total Car Mode Share (%)		70%	73%	3%	

Shading Key
X: 5% > sample average
Y: 5% < sample average

Data: Surrey New Occupiers Survey 1998 and 2001. Stayers data only (with some non respondents).

Figure 6.15: *The Stayers – Household income Design and Energy Consumption*



Correlation Analysis (Stayers)

Correlation analysis gives an indication of the strength of the relationships within the stayers data. Pearson's product moment correlation is used to examine interval data and Kendall's tau for ordinal, as shown below. Residential population density, residential population density, distance from London, public transport accessibility and household income all show significant relationships, mirroring the findings in the full Surrey New Household Occupiers sample. Jobs-housing balance again appears to be in a non-linear relationship with energy consumption.

Table 6.13: *Correlation Analysis - the Stayers*

Socio-Economic Variable	Correlation	EC98	EC01
Residential population density	Pearson Correlation	-0.092	-0.137**
	Sig. (2-tailed)	0.076	0.008
Residential population size	Kendall's Tau	0.65	0.105**
	Sig. (2-tailed)	0.104	0.009
Distance from London	Pearson Correlation	0.173**	0.237**
	Sig. (2-tailed)	0.001	0.000
Jobs-housing balance	Pearson Correlation	0.021	0.017
	Sig. (2-tailed)	0.680	0.747
Public transport accessibility	Pearson Correlation	0.122*	0.181**
	Sig. (2-tailed)	0.019	0.001
Household income	Pearson Correlation	0.129*	0.186**
	Sig. (2-tailed)	0.029	0.002
N		376	376

NB. Significance at the 5% level is shown by * and at the 1% level by **

Linear Regression Analysis (Stayers)

Linear regression analysis is useful in determing how a set of independent variables explains a proportion of the variance in a dependent variable at a particular significant level. Chapter explain the method used in more detail, and the following Chapter 7 uses linear regression more fully to examine the whole Surrey New Household Occupiers dataset. This section uses linear regression to examine just the stayers data.

Linear regression analysis requires interval, ratio or ordinal data (the latter with 5 or more categories); hence the following independent variables are used in the tests:

- "Well researched" land use variables: residential population density, residential population size, distance from London, jobs-housing balance.
- "Under researched" land use variables: public transport accessibility.
- "Well researched" socio-economic variables: number of bedrooms, number of children, car availability, company car ownership, household income, house value, sex and age.

- "Under researched" attitudinal variables: attitude to the environment, public transport, residence, mobility, time, urban environment, traffic demand management and work and surrounding mobility.

The dependent variables are energy consumption in 1998 and 2001.

The linear regression analysis results show that the land use and socio-economic variables, when considered together, explain 65% of the variation in energy consumption in 1998 and 54% in 2001 – see Tables 6.14 and 6.15. We will see in the next chapter that these results are very similar to those found in analysing the whole Surrey New Household Occupiers dataset.

Table 6.14: "Stayers" *Linear Regression (Enter) with Log Data (Land Use and Socio-Economic Variables and Energy Consumption, 1998)*

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.807	0.651	0.403	0.62221	0.651	2.629	22	31	0.007

a. Predictors: (Constant), age98log, atttimelog, respopdelog, compcarlog, attmoblog, attuvlog, atttdmlog, jhbnewlog, attworklog, caravaillog, distlonlog, attreslog, childrenlog, attptlog, respopsizelog, sex98log, housevallog, ptaccesslog, attenvlog, housincomlog, bedroomslog, SrMojtwlog

b. Dependent Variable: ec98log

Anova		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22.391	22	1.018	2.629	0.007
	Residual	12.001	31	0.387		
	Total	34.392	53			

Table 6.15: "Stayers" *Linear Regression (Enter) with Log Data (Land Use and Socio-Economic Variables and Energy Consumption, 2001)*

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.737	0.543	0.239	0.82543	0.543	1.785	22	33	0.064

a. Predictors: (Constant), SrMojtwlog, atttimelog, attptlog, attworklog, jhbnewlog, age01log, sex01log, attreslog, respopsizelog, attuvlog, childrenlog, atttdmlog, compcarlog, attmoblog, caravaillog, ptaccesslog, attenvlog, distlonlog, housevallog, respopdelog, housincomlog, bedroomslog

b. Dependent Variable: ec01log

Anova		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	26.752	22	1.216	1.785	0.064
	Residual	22.484	33	0.681		
	Total	49.236	55			

6.6 Temporal Impacts: Summary Thoughts

The temporal effect thus appears to be a very important factor in the land use, socio-economic and travel behaviour relationship. Harvey's (2000) general spatio-temporality thesis is critically relevant here, together with the the more specific Gordon and Richardson co-location thesis (1989). Empirical difficulties however are common in this research area, particularly in relation to the attrition effect. This latter issue is overcome in the Surrey analysis by using matched pair analysis – comparing respondents who answer the survey questions in both 1998 and 2001. Again note that the analysis considers the journey to work only.

We can see that the changes over time are incredibly complex and subtle. Some commutes become longer, some shorter, others stay the same distance. Some change modes, others remain the same mode. The individual volatility is huge and there appears to be a form of "travel kurtosis effect", hidden by aggregate analysis.

Certain additional disaggregations offer further insight into the temporal dimension of the land use and travel relationship. For example, it is possible to consider the different travel behaviour patterns of the "stayers", "outmovers" and "inmovers".

- The stayers: are the least energy consuming of the cohorts. However, energy consumption increases over time, by 4% from 1998-2001. This reflects trends which move in different directions - journey distance and journey time reduce (co-locate) by 4%, yet car mode share increases (dis-locates) by 3%;

- The outmovers: represent the most mobile grouping in terms of journey distance travelled, have the highest car mode share, and account for 8% more in energy consumption than the stayers in 1998;

- The inmovers: are more mobile than the stayers, but less mobile than the outmovers. They account for the greatest in energy consumption, 10% more than the stayers in 2001.

A number of nuances can be explored as to the detailed components of the co-location thesis (the kurtosis below), as outlined below:

- In terms of density, and within the Surrey data, there appears to be an important threshold effect. Co-location in terms of travel distance and energy consumption occurs at the higher population densities. At the lower population densities, only travel distance co-location occurs, and is outweighed by the increase in energy consumption;

- Over time households in the rural locations increase their average journey length and car mode share, meaning that average energy consumption increases by 11%. Only the households in the smaller towns in Surrey reduce their energy consumption over time;

- Households furthest from London increase their car mode share to the greatest extent;

- Households close to certain links on the strategic highway network - the M3, A31 and A3 - increase their energy consumption markedly, a reflection of higher car mode shares and/or longer travel distances. For example, households located near to the A31 consume 58% more energy than those located more than 3km from the strategic road network in 2001;

- Households in locations with good public transport accessibility (0-20 minutes journey time to the town centres in Surrey) reduce their average journey length, meaning that average energy consumption reduces by 2-4% from 1998-2001. Conversely, households in locations with poor public transport accessibility (>20 minutes journey time to the town centres in Surrey) increase their average journey length and/or their car mode share, meaning that average energy consumption increases by 6-9%;

- Households located in countryside beyond the Green Belt increase their energy consumption most over time – by 19%. Households located elsewhere increase their energy consumption by 3%;

- The lower income groups co-locate in distance terms, but this is outweighed, in terms of composite energy consumption, by increases in car dependency. The higher income groups dis-locate in terms of journey distance and become more reliant on the car, hence experience large increases in composite energy consumption over time.

What is beginning to become increasingly clear is the complexity of the issues involved in housing location and travel behaviour, the volatility of individual travel behaviour, and a variety of components within the co-location debate. Local and aggregate-level analysis is required if we are to understand the trends on the ground.

Correlations analysis confirms that a number of these relationships are significant. And linear regression analysis highlights that landuse and socio-economic variables account for a major part of the variation in energy consumption: 65% of the variation in 1998 and 54% in 2001.

When people choose to move, "transport" as an issue appears to enter the decision-making process at a number of levels. Sometimes the workplace location dictates the choice of resident location; in others the resident location dicates the workplace location. Most likely, there is a combination of factors: including the desire for a bigger house; a good environment; relationship change; a location close to family, friends or schools. These individual decisions manifest themselves into large movement flows at the aggregate level.

The land use, socio-economic and travel behaviour relationship is thus a classic type of organised complexity. For example density is interesting in that, at the lower population densities, only travel distance co-location occurs, and is outweighed by the increase in ca rmode share and energy consumption. And income is important in that the higher income groups, in aggregate, actually dis-locate their home and workplace locations over time and become more car dependent.

Gordon and Richardson (1989, 1991 and 1997 et al); Cervero and Landis (1992); Headicar (1997); and others; thus were along the right lines in their initial, speculative and partial reading of events. The phenomenon of journey distance (and journey time) co-location does occur in Surrey, with a periodical re-adjustment spatially of resident and workplace locations. However, the important composite measure of transport energy consumption increases, reflecting increased car dependence over time.

This thesis thus adds a systematic analysis and disaggregation of the data to the literature field and shows that co-location and dis-location occur – at the same time – depending on what level and type of analysis is used in terms of dependent variable (land use) and independent variable (travel behaviour indicator).

As discussed in the introductory text to this chapter, Tiebout (1956) introduced the concept of urban area niche, suggesting that municipalities within an urban area may specialise to attract residents. In effect, each locality develops its own market niche over time in the housing and travel interaction market. This appears to happen quite effectively in Surrey. For example, we can identify a number of specific urban area niches:

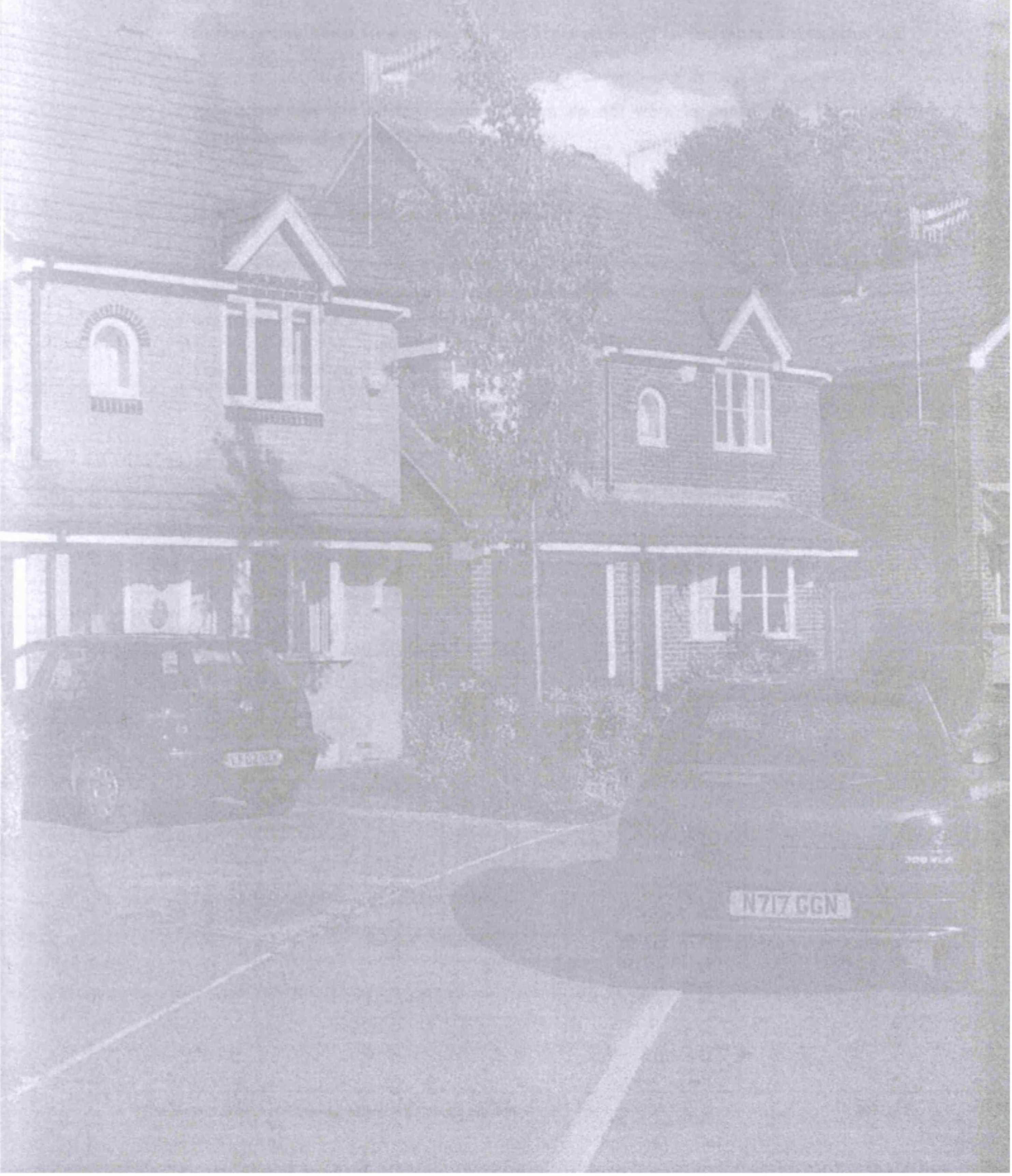
- Good rail access to London: Epsom, Woking, Guildford, Aldershot, Farnham, Dorking, Leatherhead and Reigate, etc.
- Good strategic road access: Thorpe, Addlestone, Windlesham, Lightwater, Shepperton, Walton, Weybridge, Leatherhead, Guildford, Farnham, Hindhead, Dorking, Reigate and Oxted, etc.
- London fringe: Epsom, Banstead, Chessington, Claygate, East Molesey, Walton, Shepperton, Sunbury and Egham etc.
- Remote rural location: Tilford, Elstead, Shere, Ewhurst, Coldharbour, Newdigate and Outwood etc.

Some towns of course play more than one role. Development plans and transport strategies need to design for and further this type of contextualisation and specialisation. The future planning of Surrey can therefore concentrate further on identifying future visions for the individual settlements in the county and designing their transport infrastructure and community facilities to achieve this agreed future role. Urban form plays a critical role in enabling travel behaviour; but its importance has historically being underplayed. We should start to use urban planning more positively to help achieve sustainability in the transport sector (at least in terms of reducing energy consumption in the journey to work).

07. The Interplay of Factors: Inferential Analysis

"These types of behaviour and thinking [are] external to the individual."

Durkheim, E. (1895/1997) The Rules of the Sociological Method, p.96



7. The Interplay of Factors: Inferential Analysis

Multi-criteria analysis is useful in highlighting the effects of a combination of land use and socio-economic variables on travel behaviour. Developing earlier bi-variate analysis in Chapters 4 and 5, linear regression analysis techniques are employed within this chapter. The analysis uses the complete Surrey dataset (rather than the "stayers" subset).

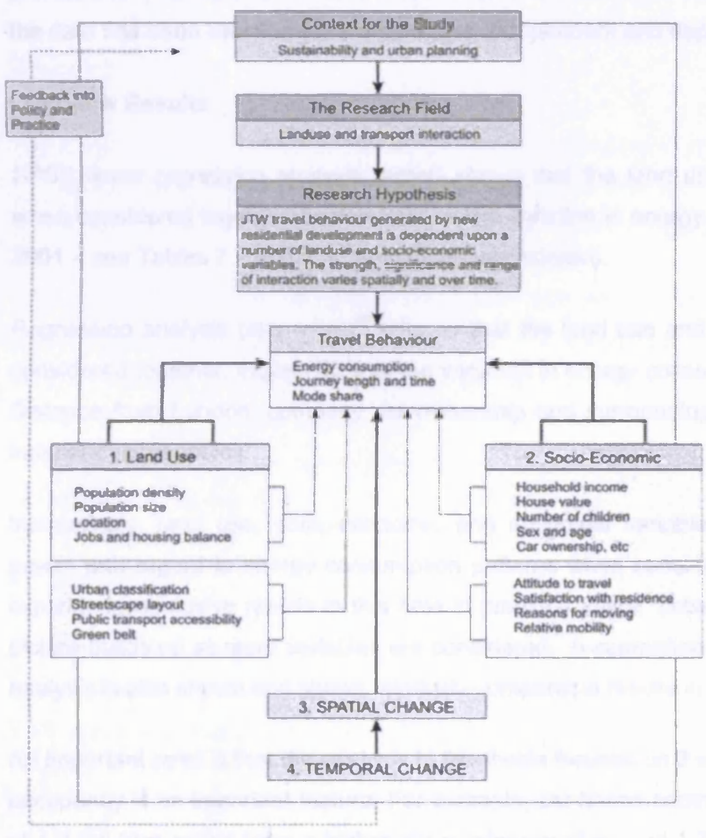
Research Question 6: How do land use and socio-economic factors relate to each other and to travel behaviour?

H_0 – Land use and socio-economic factors do not work in combination to produce individual/collective travel behaviour patterns

H_1 – Land use and socio-economic factors work in combination to produce individual/collective travel behaviour patterns

The key diagram below shows the relation of this part of the research to the rest of the empirical analysis - here we consider the inter-relationships between land use and socio-economic variables and travel behaviour.

Figure 7.1: *Interplay of Factors*



7.1 Linear Regression Analysis

Regression analysis is useful in determining that a set of independent variables explains a proportion of the variance in a dependent variable at a particular significant level (for a more detailed discussion see Chapter 3 Research Design and Method, Page 58 and Annex 5). We should note that linear regression analysis requires interval, ratio or ordinal data (the latter with 5 or more categories); hence the following independent variables are used in the tests:

- "Well researched" land use variables: residential population density, residential population size, distance from London, jobs-housing balance.
- "Under researched" land use variables: public transport accessibility.
- "Well researched" socio-economic variables: number of bedrooms, number of children, car availability, company car ownership, household income, house value, sex and age.
- "Under researched" attitudinal variables: attitude to the environment, public transport, residence, mobility, time, urban environment, traffic demand management and work and surrounding mobility.

The main dependent variables are energy consumption in 1998 and 2001, but also analysis is provided for journey distance and mode. Also to ensure linear relationships between the variables the data has been transformed using logged independent and dependent variables.

Overview Results

SPSS linear regression analysis (enter) shows that the land use and socio-economic variables, when considered together, explain 60% of the variation in energy consumption in 1998 and 54% in 2001 – see Tables 7.2 and 7.3. Results are not additive.

Regression analysis (step-wise)[49] tells us that the land use and socio-economic variables, when considered together, explain 52% of the variation in energy consumption in 1998 and 40% in 2001. Distance from London, company car ownership and surrounding mobility are the most important independent variables.

Interestingly, land use, socio-economic and attitudinal variables only have limited explanatory power with regard to energy consumption patterns when considered on their own. This perhaps explains inconclusive results in this field in previous years. Table 7.1 shows how the explanatory picture builds up as more variables are considered. A comparison with results from Stead's (1999) analysis is also shown and shows relatively comparable results in the common categories.

An important point is that the analysis in this thesis focuses on the journey to work. Hence AM peak occupancy is an important feature. For example, car-based commuting occupancy is relatively low at 1.2 (all trips would have a higher car occupancy at around 1.7). Rail occupancy is assumed to

[49] A definition of linear regression using enter and step-wise data entry techniques is given in the Annex.

be high at 90% (all trips would be lower at an occupancy of around 20-40%). If different occupancy assumptions were taken, perhaps if the analysis was focused on all trips rather than the journey to work, then the land use/socio-economic and travel relationships as expressed here would be less impressive. There would be a much smaller relative difference between modes in energy consumption terms. Occupancy, therefore, remains a very important variable.

Table 7.1: *Comparative Linear Regression (Enter) Results*

		Surrey NHOS						Stead NTS
		EC		JD		Mode		EC
		1998	2001	1998	2001	1998	2001	1999
Land use Variables	"Old"	8%	7%		-			3% (individual)
	"New"	3%	3%					-
	"All"	9%	9%					
Socio Economic Variables	"Old"	28%	32%					24% (individual)
	"New" Attitudinal Variables	3%	4%					-
All Variables		60%	54%	28%	32%	17%	18%	
"Stayers" data only		65%	54%		-			-

The regression analysis on the Surrey data therefore tells us that:

- Land use variables explain a limited amount of the variation in energy consumption (9%) in 1998 and 2001.
- Socio economic variables explain more of the variation in energy consumption in 1998 (28%) in 2001 (and 32%). It is useful to add in attitudinal variables to the picture, by themselves they explain some of the variation in energy consumption in 1998 (3%) and 2001 (4%).

The critical point in attempting to further understand the logic behind travel behaviour is that both land use and socio-economic variables need to be considered together as a package of inter-related variables. Hence the need for analyses of land use and transport to be wide-ranging in nature. Simplistic, spatial determinism is not useful here - at least in the Surrey context, and when considering new household occupiers and commuting behaviour – however it appears to be an important part of the picture.

Detailed Results

Detailed results are shown in the following tables (see Tables 7.2-7.15). Explanatory notes are given below for Table 7.2 [Linear Regression (Enter) with Log Data (Land Use and Socio-Economic Variables and Energy Consumption, 1998)].

- R^2 is the percent of the dependent explained by the independents. In this case, the independent variables explain 60% of the variation in energy consumption (which is a relatively large amount). However, we should note that other variables, which are not specified, explain a significant amount of the variance; 40% remains unknown.

- Adjusted R^2 is a standard, arbitrary downward movement adjusted to penalise for the possibility that, with many dependents, some of the variance may be due to chance. The more independents the more adjustment penalty. The adjustment here is large due to the large number of variables.

- Standard error of the estimate is 0.65. The mean of energy consumption in 1998 is 60.1 MJ. Therefore, if on a given case the prediction happened to be 60.1, we could be 95% confident that the actual value would be within plus or minus 1.96*0.65 = 1.27 MJ. The general rule of thumb is that if two standard errors are the bulk of the range of the dependent (not in this case) then any predictions using the model will be poor.

- The F value for the Change Statistics shows the significance level associated with the model. This model is significant at the 0.000 level (hence works well).

- The Anova table also shows the overall significance of the model, i.e. of the regression equation: again this model is significant at the 0.000 level (as noted above).

- The b constants and the constant can be used to create the prediction (regression) equation. Energy Consumption 1998 = (-0.001*respopdelog) + (-0.160*respopsizelog) + (0.862*distlonlog) etc. plus a constant of -3.016 (plus or minus the standard error of estimate). In practice however we are not using this model to predict energy consumption.

- The beta coefficients are the standardised regression coefficients: their relative sizes reflect their importance in predicting energy consumption.

- The t-test examines the significance of each b coefficient; it is possible to have a regression model which is significant overall by the F test, but where a particular coefficient is not significant (as in the example below).

- The zero order correlation is the original correlation of the independent variable with the dependent variable. The partial correlation is this, but with independent and dependent control variables removed. Part correlation removes the effect of the control variable on just the independent variable.

Collinearity statistics are also important: the tolerance for a variable is $1\text{-}R^2$ for the regression of a variable on all other independents, ignoring the dependent. When tolerance is close to 0 there is high multicollinearity of that variable with other independents, and the b and beta coefficients will be unstable. VIF is the variation inflation factor, which is the reciprocal of tolerance. Therefore when VIF is high there is high multicollinearity and instability of the b and beta coefficients. Another way of testing for collinearity is to examine Pearson's r between each pair of independent variables; this should not exceed 0.80. Above this figure the variables may be suspected of exhibiting multicollinearity. Below we can see that multicollinearity is not a difficulty in the Surrey NHOS data.

Table 7.2: *Linear Regression (Enter) with Log Data (Land Use and Socio-Economic Variables and Energy Consumption, 1998)*

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.77	0.60	0.46	0.65	0.60	4.39	22	65	0.000

Predictors: (Constant), surmobjtwlog, attptlog, compcarlog, atttimelog, age98log, respopsizelog, sex98log, attworklog, attuvlog, jhbnewlog, atttdmlog, attreslog, childrenlog, housincomlog, attmoblog, ptaccesslog, attenvlog, caravaillog, distlonlog, respopdelog, bedroomslog, housevallog

Anova		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	40.45	22	1.84	4.39	0.000
	Residual	27.24	65	0.42		
	Total	67.69	87			

a. Predictors: (Constant), surmobjtwlog, attptlog, compcarlog, atttimelog, age98log, respopsizelog, sex98log, attworklog, attuvlog, jhbnewlog, atttdmlog, attreslog, childrenlog, housincomlog, attmoblog, ptaccesslog, attenvlog, caravaillog, distlonlog, respopdelog, bedroomslog, housevallog

b. Dependent Variable: ec98log

Coefficients		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-3.016	3.505		-0.861	0.393		
	respopdelog	-0.001	0.093	-0.002	-0.015	0.988	0.414	2.417
	respopsizelog	-0.160	0.171	-0.085	-0.934	0.354	0.744	1.345
	distlonlog	0.862	0.384	0.278	2.248	0.028	0.405	2.466
	jhbnewlog	0.098	0.149	0.061	0.658	0.513	0.715	1.399
	ptaccesslog	0.077	0.184	0.049	0.416	0.679	0.443	2.257
	bedroomslog	-0.365	0.481	-0.110	-0.760	0.450	0.297	3.367
	childrenlog	-0.143	0.195	-0.073	-0.735	0.465	0.627	1.595
	compcarlog	-0.895	0.256	-0.315	-3.494	0.001	0.761	1.315
	caravaillog	0.275	0.246	0.117	1.115	0.269	0.562	1.779
	housincomlog	-0.142	0.195	-0.075	-0.730	0.468	0.593	1.685
	housevallog	0.147	0.248	0.089	0.594	0.554	0.275	3.637
	sex98log	-0.260	0.240	-0.096	-1.082	0.283	0.782	1.278
	age98log	0.379	0.446	0.079	0.849	0.399	0.716	1.396

	0.296	0.169	1.637	0.106	0.579	1.728
	0.233	0.008	0.074	0.941	0.572	1.748
	0.304	-0.058	-0.615	0.541	0.689	1.452
	0.632	0.105	1.105	0.273	0.684	1.461
	0.456	0.329	3.762	0.000	0.811	1.233
	0.287	-0.269	-2.871	0.006	0.708	1.413
	0.180	-0.132	-1.446	0.153	0.743	1.345
	0.188	-0.059	-0.674	0.503	0.803	1.246
	0.146	0.126	0.906	0.369	0.318	3.144

ear regression with the enter method) are as below (see Table 7.3):

nd socio-economic independent variables explain 54% of the variation in energy consumption (which is a relatively large amount). e that other variables, which are not specified, explain a significant amount of the variance; 46% remains unknown.

timate is 0.72. The mean of energy consumption in 2001 is 59.4 MJ. Therefore, if on a given case the prediction happened to be onfident that the actual value would be within plus or minus 1.96*0.72 = 1.41 MJ.

nge Statistics shows the significance level associated with the model. This model is significant at the 0.000 level (hence works al coefficients within the model are not significant.

Table 7.3: *Linear Regression (Enter) with Log Data (Land Use and Socio-Economic Variables and Energy Consumption, 2001)*

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.73	0.54	0.36	0.72	0.54	3.02	22	57	0.000

a. Predictors: (Constant), surmobjtwlog, respopsizelog, compcarlog, atttimelog, age01log, jhbnewlog, attuvlog, attptlog, sex01log, attworklog, caravaillog, atttdmlog, attreslog, childrenlog, attmoblog, attenvlog, ptaccesslog, housincomlog, distlonlog, respopdelog, bedroomslog, housevallog

Anova		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	34.38	22	1.56	3.02	0.000
	Residual	29.49	57	0.52		
	Total	63.87	79			

a. Predictors: (Constant), surmobjtwlog, respopsizelog, compcarlog, atttimelog, age01log, jhbnewlog, attuvlog, attptlog, sex01log, attworklog, caravaillog, atttdmlog, attreslog, childrenlog, attmoblog, attenvlog, ptaccesslog, housincomlog, distlonlog, respopdelog, bedroomslog, housevallog

b. Dependent Variable: ec01log

Coefficients		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2.599	4.156		0.625	0.534		
	respopdelog	0.027	0.104	0.036	0.261	0.795	0.433	2.312
	respopsizelog	-0.056	0.201	-0.029	-0.277	0.783	0.734	1.362
	distlonlog	0.317	0.448	0.102	0.709	0.481	0.393	2.544
	jhbnewlog	0.036	0.181	0.021	0.200	0.842	0.707	1.414
	ptaccesslog	0.073	0.209	0.047	0.350	0.728	0.444	2.251
	bedroomslog	-0.172	0.550	-0.050	-0.312	0.756	0.313	3.199
	childrenlog	-0.056	0.230	-0.028	-0.243	0.809	0.616	1.624
	compcarlog	-1.102	0.305	-0.387	-3.613	0.001	0.706	1.416
	caravaillog	0.446	0.280	0.198	1.595	0.116	0.528	1.894
	housincomlog	-0.066	0.273	-0.034	-0.244	0.808	0.419	2.388
	housevallog	0.029	0.305	0.017	0.097	0.923	0.257	3.890
	Sex01log	-0.562	0.294	-0.209	-1.913	0.061	0.681	1.469
	Age01log	0.790	0.547	0.153	1.444	0.154	0.722	1.385

attenvlog	0.277	0.339	0.098	0.819	0.416	0.566	1.768
attptlog	-0.221	0.274	-0.099	-0.807	0.423	0.543	1.841
attreslog	-0.653	0.405	-0.181	-1.612	0.113	0.642	1.559
attmoblog	-0.127	0.835	-0.018	-0.152	0.880	0.576	1.738
atttimelog	1.136	0.540	0.217	2.105	0.040	0.763	1.310
attuvlog	-0.670	0.297	-0.239	-2.256	0.028	0.719	1.391
atttdmlog	-0.413	0.216	-0.201	-1.907	0.062	0.730	1.371
attworklog	-0.351	0.224	-0.158	-1.568	0.123	0.798	1.253
surmobjtwlog	0.317	0.176	0.302	1.797	0.078	0.287	3.481

Dependent Variable: ec01log

The main findings, using step-wise linear regression, are as below (see Table 7.4):

- In 1998, the land use and socio-economic independent variables (distance from London, company car ownership, attitude to time, attitude to urban village and attitude to the environment) explain 52% of the variation in energy consumption. However, we should note that other variables, which are not specified, explain a significant amount of the variance; 48% remains unknown.

- Standard error of the estimate for this model based on 5 independent variables is 0.49.

- The F value for the Change Statistics shows the significance level associated with the model. This model is significant at the 0.046 level.

- Other model variants provide greater significance (at the 0.000 level) – including independent variables distance from London, company car ownership, attitude to time.

Table 7.4: *Linear Regression (Step-Wise) with Log Data (Land Use and Socio-Economic Variables and Energy Consumption, 1998)*

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.47	0.22	0.21	0.79	0.22	23.84	1	86	0.000
2	0.58	0.34	0.32	0.73	0.12	15.83	1	85	0.000
3	0.68	0.46	0.45	0.66	0.12	19.40	1	84	0.000
4	0.70	0.50	0.47	0.64	0.03	5.05	1	83	0.027
5	0.72	0.52	0.49	0.63	0.02	4.12	1	82	0.046

a. Predictors: (Constant), distlonlog

b. Predictors: (Constant), distlonlog, compcarlog

c. Predictors: (Constant), distlonlog, compcarlog, atttimelog

d. Predictors: (Constant), distlonlog, compcarlog, atttimelog, attuvlog

e. Predictors: (Constant), distlonlog, compcarlog, atttimelog, attuvlog, attenvlog

Anova		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14.69	1	14.69	23.84	0.000
	Residual	52.99	86	0.62		
	Total	67.69	87			
2	Regression	23.01	2	11.50	21.89	0.000
	Residual	44.68	85	0.53		
	Total	67.69	87			
3	Regression	31.39	3	10.46	24.22	0.000
	Residual	36.30	84	0.43		
	Total	67.69	87			
4	Regression	33.47	4	8.37	20.30	0.000
	Residual	34.21	83	0.41		
	Total	67.69	87			
5	Regression	35.11	5	7.02	17.67	0.000
	Residual	32.58	82	0.40		
	Total	67.69	87			

Dependent Variable: ec98log

Coefficients		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-1.32	1.09		-1.21	0.231		
	distlonlog	1.45	0.30	0.47	4.88	0.000	1.00	1.00
	(Constant)	-0.27	1.04		-0.26	0.794		
2	distlonlog	1.30	0.28	0.42	4.71	0.000	0.98	1.02
	compcarlog	-1.00	0.25	-0.35	-3.98	0.000	0.98	1.02
	(Constant)	-2.37	1.06		-2.24	0.027		
3	distlonlog	1.15	0.25	0.37	4.54	0.000	0.96	1.04
	compcarlog	-1.04	0.23	-0.36	-4.52	0.000	0.98	1.02
	atttimelog	1.86	0.42	0.36	4.40	0.000	0.98	1.02
4	(Constant)	-1.77	1.07		-1.65	0.102		
	distlonlog	1.13	0.25	0.36	4.56	0.000	0.96	1.04
	compcarlog	-1.03	0.22	-0.36	-4.60	0.000	0.98	1.02
5	atttimelog	1.94	0.41	0.37	4.69	0.000	0.97	1.03
	attuvlog	-0.54	0.24	-0.18	-2.25	0.027	0.99	1.01
	(Constant)	-1.95	1.05		-1.86	0.067		

a. Dependent Variable: ec98log

The main findings, using step-wise linear regression, are as below (see Table 7.5):

- In 2001, the land use and socio-economic independent variables (company car ownership, surrounding mobility - journey to work, attitude to traffic demand management and attitude to time) explain 40% of the variation in energy consumption. However, we should note that other variables, which are not specified, explain a significant amount of the variance; 60% remains unknown.
- Standard error of the estimate for this model based on 4 independent variables is 0.71.
- The F value for the Change Statistics shows the significance level associated with the model. This model is significant at the 0.043 level.
- Other model variants provide greater significance (at least at the 0.005 level) – including independent variables any car ownership, surrounding mobility - journey to work, attitude to traffic demand management.

Table 7.5: *Linear Regression (Step-Wise) with Log Data (Land Use and Socio-Economic Variables and Energy Consumption, 2001)*

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.46	0.21	0.20	0.81	0.21	20.39	1	78	0.000
2	0.55	0.30	0.28	0.76	0.10	10.49	1	77	0.002
3	0.61	0.37	0.35	0.73	0.07	8.18	1	76	0.005
4	0.64	0.40	0.37	0.71	0.03	4.22	1	75	0.043

a. Predictors: (Constant), compcarlog

b. Predictors: (Constant), compcarlog, surmobjtw

c. Predictors: (Constant), compcarlog, surmobjtw, atttdmlog

d. Predictors: (Constant), compcarlog, surmobjtw, atttdmlog, atttimelog

Anova		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13.24	1	13.24	20.39	0.000
	Residual	50.63	78	0.65		
	Total	63.87	79			
2	Regression	19.31	2	9.65	16.68	0.000
	Residual	44.56	77	0.58		
	Total	63.87	79			
3	Regression	23.64	3	7.88	14.88	0.000
	Residual	40.23	76	0.53		
	Total	63.87	79			
4	Regression	25.78	4	6.45	12.69	0.000
	Residual	38.09	75	0.51		
	Total	63.87	79			

Dependent Variable: ec01log

Coefficients		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	4.69	0.17		27.95	0.000		
	compcarlog	-1.30	0.29	-0.46	-4.52	0.000	1.00	1.00

1	0.29		13.44	0.000		
1	0.27	-0.46	-4.85	0.000	1.00	1.00
2	0.10	0.31	3.24	0.002	1.00	1.00
5	0.30		14.02	0.000		
8	0.26	-0.45	-4.91	0.000	1.00	1.00
8	0.10	0.36	3.92	0.000	0.95	1.05
5	0.19	-0.27	-2.86	0.005	0.95	1.05
1	0.76		3.70	0.000		
7	0.25	-0.44	-4.97	0.000	1.00	1.00
8	0.10	0.36	3.96	0.000	0.95	1.05

as the dependent variable, and using enter linear regression, provides less conclusive results (see Table 7.6):

nd socio-economic independent variables explain 28% of the variation in energy consumption. However, we should note that other t specified, explain a significant amount of the variance; 72% remains unknown.

stimate for this model is 0.76.

ange Statistics shows a reduced significance level associated with the model at 0.012.

nter) with Log Data (Land Use and Socio-Economic Variables and Journey Distance, 1998)

	R Square	Adjusted R Square	Std. Error of the Estimate	Sig. F Change
	0.28	0.15	0.76	0.012

ɔg, jhbnewlog, respopsizelog, sex98log, compcarlog, childrenlog, age98log, caravaillog, ptaccesslog, housincomlog, distlonlog, bedroomslog,

Squares	df	Mean Square	F	Sig.
.22	14	1.30	2.24	0.012
.95	81	0.58		
.17	95			

Jnstandardized Coefficients		Standardized Coefficients	t	Sig.
B	Std. Error	Beta		
3.59	3.76		0.96	0.342
-0.16	0.10	-0.23	-1.65	0.104
-0.33	0.19	-0.18	-1.70	0.094
0.45	0.38	0.15	1.18	0.242
0.18	0.16	0.12	1.12	0.265
-0.03	0.19	-0.02	-0.15	0.880
0.01	0.51	0.00	0.02	0.982
-0.12	0.21	-0.07	-0.60	0.553
0.08	0.26	0.04	0.31	0.757
-0.36	0.27	-0.14	-1.34	0.184
-0.12	0.22	-0.07	-0.57	0.572
-0.04	0.27	-0.03	-0.16	0.875
-0.71	0.27	-0.27	-2.64	0.010
-0.25	0.48	-0.06	-0.52	0.604
0.16	0.33	0.07	0.48	0.631

The main findings (Table 7.7) are that:

- In 2001, the land use and socio-economic independent variables explain 32% of the variation in energy consumption. However, we should note that other variables, which are not specified, explain a significant amount of the variance; 68% remains unknown.
- Standard error of the estimate for this model is 24.16.
- The F value for the Change Statistics shows a significance level associated with the model at 0.003.

Table 7.7: *Linear Regression (Enter) with Log Data (Land Use and Socio-Economic Variables and Journey Distance, 2001)*

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate	Sig. F Change
1	0.57	0.32	0.20	24.16	0.003

a. Predictors: (Constant), SrMojtwlog, compcarlog, respopsizelog, age01log, jhbnewlog, sex01log, caravaillog, childrenlog, ptaccesslog, housincomlog, distlonlog, respopdelog, bedroomslog, housevallog

Anova		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22,133.01	14	1,580.93	2.71	0.003
	Residual	46,682.62	80	583.53		
	Total	68,815.63	94			

Coefficients		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	28.10	124.34		0.23	0.822
	respopdelog	-1.94	3.08	-0.08	-0.63	0.530
	respopsizelog	-10.73	6.27	-0.17	-1.71	0.091
	distlonlog	14.41	12.08	0.15	1.19	0.237
	jhbnewlog	4.31	5.14	0.09	0.84	0.404
	ptaccesslog	6.23	5.79	0.13	1.08	0.285
	bedroomslog	-16.16	15.50	-0.16	-1.04	0.300
	childrenlog	-7.13	6.80	-0.12	-1.05	0.297
	caravaillog	4.49	7.76	0.07	0.58	0.565

-16.31	8.71	-0.19	-1.87	0.065
12.84	7.39	0.22	1.74	0.086
-1.91	8.98	-0.04	-0.21	0.832
-14.48	8.79	-0.17	-1.65	0.103
0.86	15.79	0.01	0.05	0.957
7.07	10.64	0.10	0.66	0.508

ıe dependent variable, and using enter linear regression, again provides less conclusive results (Table 7.8):

ınd socio-economic independent variables explain 17% of the variation in energy consumption. However, we should note that other ıt specified, explain a significant amount of the variance; 83% remains unknown. The modelling therefore does not work particularly :io-economic variables are not accounting for a large amount of the variation in mode share.

stimate for this model is 0.59.

ınge Statistics shows a reduced significance level associated with the model at 0.151.

nter) with Log Data (Land Use and Socio-Economic Variables and Mode, 1998)

	R Square	Adjusted R Square	Std. Error of the Estimate	Sig. F Change
	0.17	0.05	0.59	0.151

og, compcarlog, respopsizelog, sex98log, childrenlog, jhbnewlog, age98log, caravaillog, housincomlog, distlonlog, ptaccesslog, bedroomslog,

Squares	df	Mean Square	F	Sig.
00	14	0.50	1.44	0.151
.36	96	0.35		
.35	110			

Jnstandardized Coefficients		Standardized Coefficients	t	Sig.
B	Std. Error	Beta		
3.45	2.82		1.22	0.224
-0.02	0.07	-0.05	-0.35	0.729
-0.07	0.15	-0.05	-0.45	0.653
-0.39	0.28	-0.18	-1.40	0.164
-0.21	0.12	-0.20	-1.83	0.071
0.07	0.13	0.07	0.54	0.588
0.12	0.35	0.05	0.34	0.734
0.18	0.15	0.13	1.25	0.216
-0.01	0.17	0.00	-0.03	0.972
0.17	0.19	0.09	0.89	0.378
-0.09	0.15	-0.07	-0.64	0.525
-0.12	0.20	-0.10	-0.59	0.559
-0.60	0.20	-0.31	-3.03	0.003
0.17	0.35	0.05	0.48	0.631
0.01	0.22	0.01	0.05	0.963

e that:

nd socio-economic independent variables explain 18% of the variation in energy consumption. However, we should note that other specified, explain a significant amount of the variance; 82% remains unknown. The modelling therefore remains inconclusive - land c variables are not accounting for a large amount of the variation in mode share.

stimate for this model is 0.692.

nge Statistics shows a significance level associated with the model at 0.130.

nter) with Log Data (Land Use and Socio-Economic Variables and Mode, 2001)

	R Square	Adjusted R Square	Std. Error of the Estimate	Sig. F Change
	0.18	0.06	0.692	0.130

og, compcarlog, respopsizelog, sex01log, childrenlog, jhbnewlog, age01log, caravaillog, housincomlog, distlonlog, ptaccesslog, bedroomslog,

Squares	df	Mean Square	F	Sig.
83	14	0.70	1.49	0.130
.25	94	0.47		
.08	108			

Jnstandardized Coefficients		Standardized Coefficients	t	Sig.
B	Std. Error	Beta		
1.02	3.32		0.31	0.759
-0.09	0.08	-0.15	-1.12	0.266
-0.29	0.17	-0.18	-1.72	0.089
-0.50	0.33	-0.20	-1.52	0.132
0.07	0.14	0.06	0.55	0.585
0.01	0.16	0.01	0.05	0.957
0.40	0.42	0.15	0.97	0.335
-0.01	0.17	-0.01	-0.05	0.957

caravaillog	-0.26	0.20	-0.15	-1.30	0.196
compcarlog	0.42	0.23	0.18	1.85	0.068
housincomlog	-0.34	0.18	-0.23	-1.91	0.059
housevallog	0.15	0.23	0.11	0.66	0.511
Sex01log	-0.38	0.23	-0.17	-1.64	0.105
Age01log	-0.03	0.42	-0.01	-0.07	0.944
SrMojtwlog	-0.10	0.27	-0.06	-0.37	0.712

a. Dependent Variable: mode01log

Similarly when linear regression modelling is performed at the disaggregated level – using land use variables as independent variables, or socio-economic or attititudinal variables as independent variables then R squares fall (see Tables 7.10-7.15).

For example, land use variables explain 9% of the variation in energy consumption in 1998 and 2001; attitudinal variables explain 3-4% of the variation in energy consumption in 1998 and 2001; and socio-economic variables explain 28-31% of the variation in energy consumption in 1998 and 2001.

The modelling therefore works best when land use, attitudinal and socio-economic variables are considered together as independent variables contributing to energy consumption in the journey to work.

Enter) with Log Data (Land Use Variables and Energy Consumption, 1998)

	R Square	Adjusted R Square	Std. Error of the Estimate	Sig. F Change
	0.09	0.08	0.74	0.000

nlog, respopsizelog, ptaccesslog, distlonlog, respopdelog, tclog, jhbnewlog, dfhighwalog

Enter) with Log Data (Land Use Variables and Energy Consumption, 2001)

	R Square	Adjusted R Square	Std. Error of the Estimate	Sig. F Change
	0.09	0.05	0.74	0.012

nlog, respopsizelog, jhbnewlog, respopdelog, dfhighwalog, tclog, distlonlog, ptaccesslog

Enter) with Log Data (Attitudinal Variables and Energy Consumption, 1998)

	R Square	Adjusted R Square	Std. Error of the Estimate	Sig. F Change
	0.03	0.01	0.78	0.131

tuvlog, atttimelog, atttdmlog, attmoblog, attreslog, attenvlog, attptlog

Enter) with Log Data (Attitudinal Variables and Energy Consumption, 2001)

	R Square	Adjusted R Square	Std. Error of the Estimate	Sig. F Change
	0.04	0.01	0.84	0.136

tmoblog, attenvlog, atttimelog, atttdmlog, attreslog, attuvlog, attptlog

Enter) with Log Data (Socio-Economic Variables and Energy Consumption, 1998)

	R Square	Adjusted R Square	Std. Error of the Estimate	Sig. F Change
	0.28	0.16	0.79	0.010

housetenlog, occuplog, compcarlog, age98log, qualificlog, childrenlog, sex98log, caravaillog, housetyplog, housincomlog, housevallog, maritallog,

Enter) with Log Data (Socio-Economic Variables and Energy Consumption, 2001)

	R Square	Adjusted R Square	Std. Error of the Estimate	Sig. F Change
	0.31	0.19	0.83	0.004

mpcarlog, age01log, caravaillog, occuplog, housetenlog, childrenlog, sex01log, housetyplog, housevallog, maritallog, housincomlog, bedroomslog

7.2 Conclusions

Durkheim's (1895) notion of society, with the whole being greater than the sum of the parts, is relevant to research such as examined in this thesis. In examining the interaction of land use and travel, we are, in effect, attempting to understand the rationale behind one part of the workings of life itself. Our analysis thus needs to move beyond understanding the actions of individual people (methodological individualism) and often captured with bivariate analysis, towards an understanding of aggregate behaviour and complex relationships. Regression analysis helps here as it is very powerful in exploring multiple relationships and in assessing how individual variables are associated with each other.

An important finding from this analysis is that each land use and socio-economic variable offers very limited explanatory power in explaining travel behaviour when considered on an individual basis, or even when considered in small groupings (for example, just land use variables, or just socio-economic variables). This perhaps explains inconclusive results in this field in many previous studies. This is also to be expected – we would not expect clear, significant relationships at the individual variable level.

The important point is that when a wide range of land use and socio-economic variables are analysed together, the linear regression modelling begins to make more sense. Land use and socio-economic variables together explain a major part of the change in energy consumption in the commute to work. This, intuitively, feels correct. Travel behaviour is the result of a myriad of factors, previous analyses have only 'scratched at the surface' of understanding. This thesis begins to unravel the complexity and subtlety involved.

A number of more detailed findings are also apparent and would be worth testing with other datasets. Socio-economic characteristics appear to be more important in explaining variations in travel behaviour than land use variables. Attitudinal characteristics are of a similar order of importance to land use variables, but potentially less so. A wide range of land use and socio-economic variables are associated with travel behaviour, much wider than those traditionally considered in the literature. In particular, public transport accessibility, the green belt, neighbourhood design, attitudes to transport and relative mobility are important in explaining some variation in travel. Yet these factors have received little, if any, attention in the previous literature.

A further point to emphasise is that land use is still very much part of the argument - land use still matters in being a major contributory factor in transport energy consumption, at least in the journey to work. Spatial urban structure, at the strategic and local level, can help to enable sustainability in transport. Urban planning is thus a very much under-estimated tool that can be used to facilitate reduced energy consumption in travel.

In addition, land use characteristics (perhaps alongside attitudes to transport) are more easily manipulated than socio-economic characteristics in the search for reduced energy consumption in the transport sector. We can (relatively) easily raise densities around the public transport network, concentrate development in certain urban areas or in particular locations, achieve jobs and housing balance, aim for polycentric development and achieve good neighbourhood streetscape layout. We can also act to promote pro-public transport, walking and cycling attitudes.

All of these actions would potentially help to reduce energy consumption levels. Importantly most of these initiatives are critical for wider reasons than reduced energy consumption - most would help reduce carbon emissions (and impact on efforts to reduce global warming) and improve the *quality of life* in our towns and cities.

Again these arguments seem to be hugely underplayed in the literature and in practice: the twin objectives of reduced environmental impact and improved quality of life work together in many ways. We therefore need concerted action in this field - land use needs to be designed to reduce the transport footprint of our urban areas. Land use changes at a rate of 1-2% each year, hence we have a real opportunity for change over time. This applies even more so in areas of major development change, e.g. a new housing or retail development, or indeed settlement extensions or the new growth areas.

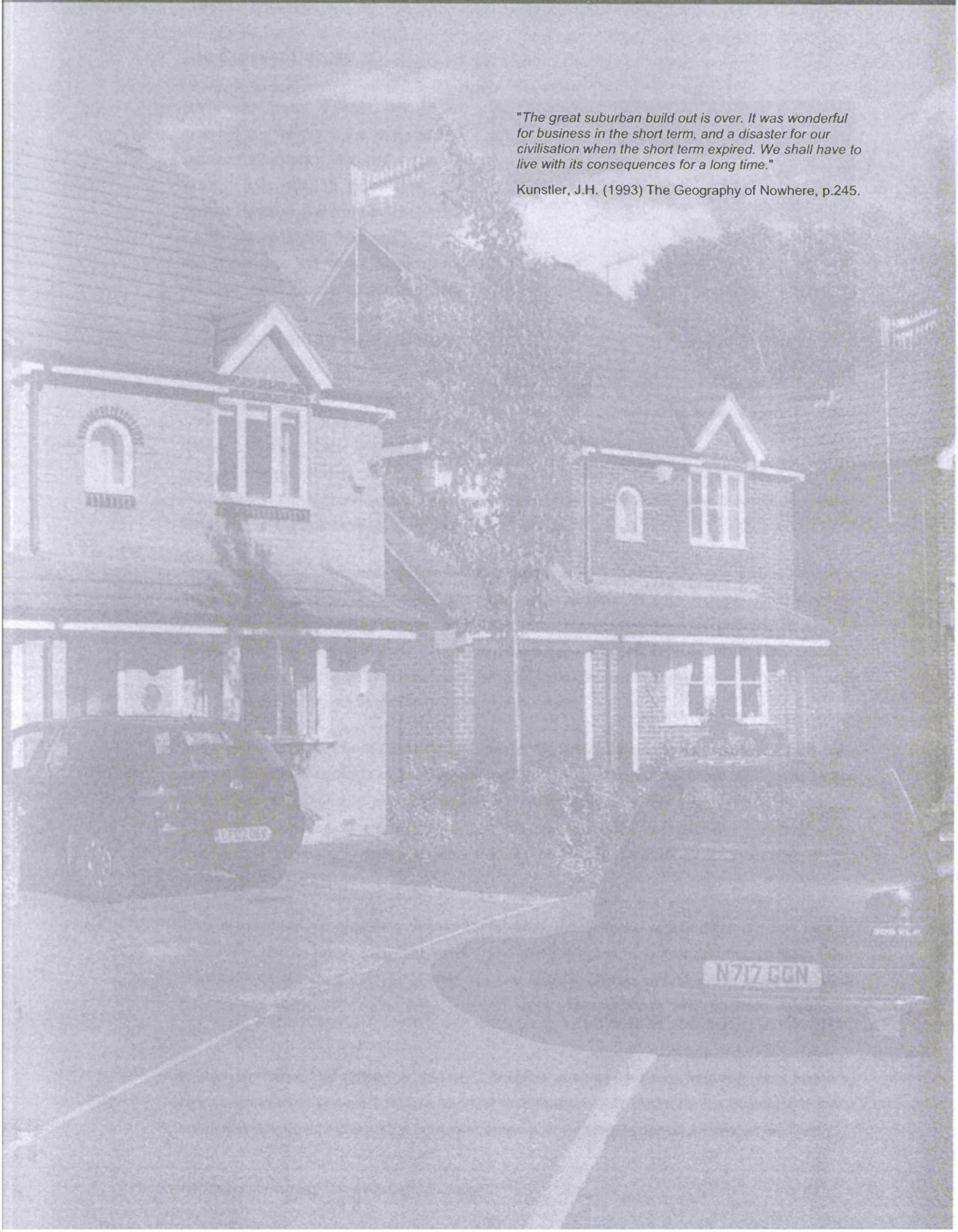
A call for realism: the transport economists do have some valid points: socio-economic characteristics remain critical in influencing travel behaviour. However, we should remember that they are less easy to utilise in the search for reduced energy consumption. It would be folly to suggest a sustainable transport strategy based on reduced income levels, reduced house sizes or part-time employment (although all of these are strongly correlated with reduced energy consumption in the commute to work). Withstanding this, there are socio-economic dimensions that can be used to support a re-focused urban form approach. Raising the price of transport and/or equitably rationing consumption (based on carbon emissions or energy consumption levels) would have the desired effect of facilitating reduced travel energy consumption. There are of course serious implementation difficulties with any such rationing schemes - and again these need to be the focus of much more research. Hickman and Banister (2005b) provide more analysis of the likely measures required to reduce carbon emissions in the UK.

The policy implication here is that we need to work harder to integrate urban planning and transport - so that both disciplines work together in mutually reinforcing ways - particularly in regional and local urban planning strategies and transport strategies. Efforts aimed at reducing energy consumption in the commute to work need to include a wide range of contributory measures. The specific approach for each area needs to be tailored to each particular context. It is perhaps here that earlier efforts to reduce travel have not succeeded as we might have expected. They have tended to be limited in scope, have not included actions covering the range of likely influences, and lacked much in the way of contextuality. Our overall objective in this revised emphasis should be in improving our quality of life - a broader goal that, for example, moves us beyond the narrow New Approach to Transport Appraisal objectives (NATA, DfT, 1998): improving safety, accessibility, the environment and economy, etc.

Too much current transport planning practice ignores wider urban planning and design objectives; and too much current urban planning and design ignores transport planning objectives. There is much to be learned and gained from multi-disciplinary working. Our transport investment strategies should enable good urban design and improved quality of life; our urban planning strategies should equally enable a sustainable transport future.

We therefore need to get the various layers of analysis and planning correct – for example appropriate design in terms of resident and workplace population density, population size, public transport accessibility, limited access to a free flowing strategic road network, distance from London and local neighbourhood layout, etc. - combined with an effective balance of socio-economic and attitudinal characteristics. This means urban planning and transport planning intervention at different scales – strategic and local. If any of these variables are not designed in an appropriate manner, the opportunity for reducing energy consumption in the commute to work may not be exploited as far as we would expect. This may, to a certain extent, explain the limited previous success in reducing our reliance on the private car. We should start by considering the type of future society we aspire to - and tailor our future (integrated) urban and transport planning strategy to facilitate the achievement of this.

08. Research Synthesis and Conclusions



"The great suburban build out is over. It was wonderful for business in the short term, and a disaster for our civilisation when the short term expired. We shall have to live with its consequences for a long time."

Kunstler, J.H. (1993) The Geography of Nowhere, p.245.

8. Research Synthesis and Conclusions

8.1 The Current Debate

There has been a huge amount of research and debate in the land use and transport interaction field in the last 30 years - it is now 18 years since the original Newman and Kenworthy (1989a) thesis. Much of the following research has shown that the varied relationships between land use and transport are complex. Much of the research has been inconclusive, and as a result, the role of urban planning in influencing travel behaviour has been underplayed. On the ground, certainly, progress has been difficult to make, there is little sign of reduced energy consumption in our travel behaviour. This is particularly relevant in suburban areas, where the public transport orientated development logic, with higher densities developed around public transport nodes, has been less easy to apply.

Through detailed analyses of the data we are beginning to understand the complexity of the issues, the need for multi-disciplinary thinking; and how we might seek to more effectively reduce travel by design

Researchers such as Newman and Kenworthy, Gordon and Richardson, Cervero, Crane, Kitamura, Banister, Hall, Headicar, and Breheny, etc. have led the research field, for example, developing our thinking on topics such as density, population size, jobs-housing balance and the location of development, or critiquing the field, suggesting that income might be more important than density in being associated with energy consumption, or that public opinion is not in support of higher density design (hence the academic debate becomes unimportant).

In the last few years, through detailed analyses of the data, a [broadly] consistent evidence base and policy viewpoint is however beginning to emerge. Most authors believe that the current growth in traffic is unsustainable and that transport has an important role to play in developing a sustainable future for our cities. Although it has proved difficult to isolate the effects of urban planning on travel behaviour, the vast majority of authors believe there are some causal relationships at work.

More researchers are beginning to unpick the detail - to understand that there is some logic to urban form and to urban form and travel - and are beginning to understand the complex inter-relationships between the range of land use and socio-economic variables and travel behaviour (see Stead, 1999; Schwanen, 2003; Nielsen, 2004; and Hickman and Banister, 2005a; for example).

In *Sociable Cities*, Hall (2000, pp. 151-154) provides a useful synthesis, with the usual historical context, concluding that the land use and transport interaction literature field is beginning to tell a consistent story, and that a number of key strategic policy elements can be developed, including:

1. Developing urban nodes: systematic efforts should be made to create new accessibility nodes by selective investment in new transport links. A polycentric model can balance flows along public transport corridors. Major efforts should be made to improve orbital links, since radial links are, as a general rule, much better developed. The Swedish principle of pyramids of density, used in the Stockholm satellite towns, should be developed in the UK.

2. Selective urban densification: urban compaction or intensification is desirable in order to help regeneration and renaissance, induce less use of the car and protect the open countryside.

3. No 'town cramming': densification must be compatible with good urban quality. Urban open spaces must be rigorously protected.

4. Strategic provision for greenfield development: this is perhaps the most controversial proposal for a county such as Surrey. But, because selective densification can never hope to provide more than half of the national housing demand, the residue will need to be accommodated elsewhere. A regional strategy will thus be critical, crossing borough, county and sub-regional borders.

5. Clustered new development: an updated, linear version of Howard's Social City, with relatively small-scale residential communities (20,000-30,000 population) focused along public transport routes, especially rail, light rail and guided busway. Breheny, Rookwood and Calthorpe provide the way forward here.

6. Town expansions: clustered development can contain a mixture of different types of development. Medium sized and smaller towns with good public transport accessibility can be expanded. New towns may be an appropriate solution; at times better than an ad-hoc 'pepperpotting' of development, which makes often little strategic sense.

7. Areas of tranquillity: large areas of countryside should be protected to conserve tranquillity, with development restricted to only that which meets local needs.

Other 'high-level' theorists offer viewpoints that are useful to those interested in the land use/transport interaction field. The Castells (1999) viewpoint here is to understand the complexity of cities and to consider what our broad objectives might be in city planning. For example, few urban areas conform to the 'stereotypical' form; most have high density and low density quarters to them. There is little use in simplifying the argument. Also "*the intellectual debate at the turn of the millennium is a debate on the state and prospects of human civilisation.*" (Castells, 1999, p.367). Urban planning and transport planning, and the integration of the disciplines, hence needs to be understood as a tool in developing civilisation.; and the new spatial geography needs to be inextricably linked to a social perspective, i.e. to aid improvements to our collective quality of life.

Harvey (1990, p.204) adds considerations of spatial-temporal-social interactions: "*from a materialistic perspective ... objective conceptions of time and space are necessarily created through material practices and processes which serve to reproduce social life ... it is a fundamental axiom ... that time and space cannot be understood independently of social action.*"

8.2 Moving Beyond Current Thought: Key Research Findings

The research in this thesis has helped to build on progressive thinking in the literature field.

The main study hypothesis is that:

"Journey to work travel behaviour generated by new residential development is dependent on a number of land use and socio-economic variables. The strength, significance and range of interaction vary spatially and over time."

The thesis's particular contribution is as outlined below:

- An examination of the complexity of the land use and transport interaction field, using energy consumption as the dependent variable (calculated using a combination of journey to work distance, mode, frequency and occupancy).

- An estimation of the strength and significance of a wide range of land use and socio-economic variables - both previously researched and under researched variables - including factors such as local neighbourhood design, public transport accessibility and attitude to travel.

- A segmentation of respondents into different groups such as stayers, inmovers and outmovers, showing the different manifestation of the land use and transport relationship for different groups within society.

- An assessment of the impact of time on the land use and transport relationship, with temporality and adaptation noted as critical features of travel behaviour, and potential attrition factors controlled for.

- The use of a seldom-studied London fringe county in Surrey - much previous work is concentrated on the city or other urban areas.

This final chapter synthesises the research analysis into a number of key findings. It aims to further our understanding of the complexity of travel behaviour and the effects of spatio-temporality. The analysis is based on the journey to work. This is used rather than all trip types to highlight the strong relationship between housing and employment location and how this might change over time, and also was a result of what was available data-wise from new household survey type analysis.

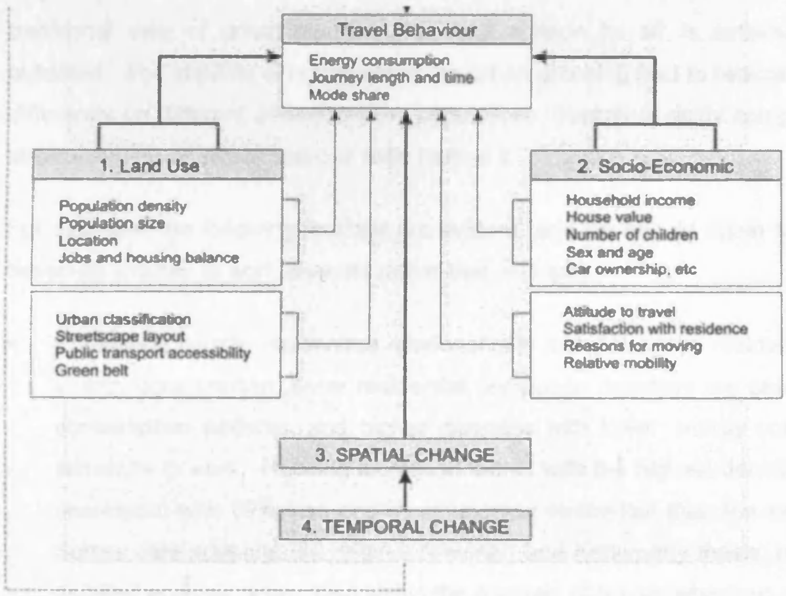
Travel behaviour associated with new housing development in Surrey is getting ever more complicated. Mobility has 'stepped up': with travel patterns becoming multi-layered; urban sprawl and concentration have simultaneously occurred; leading to tangential and orbital movements; housing and workplace co-location and dislocation; and stretch commuting. Traditional distinctions have become blurred, new urban forms are developing, residential and employment centres are located within and on the edge of urban centres (as are other facilities). The traditional radial commute to the urban centre is less common; new and highly complex travel patterns are becoming more evident. The resulting environmental, economic and social problems (and opportunities) are reaching new levels. Our understanding of this increased complexity is however very much under-developed, and we continue to underestimate the role that urban planning can play in facilitating (and manipulating) travel.

A host of factors are associated with an individual's travel behaviour. This research has identified and examined the following contributing factors:

- Land use: including resident population density, resident employment density, workplace population density, workplace employment density, resident population size, workplace population size, distance from urban centres and strategic transport networks, jobs-housing balance, resident location (relative to the urban area), type of journey to work, neighbourhood urban design, public transport accessibility, and resident location (relative to the green belt).
- Socio-economic: household tenure, house type, house size, number of children, car availability, company car ownership, household income, house value, respondent sex, respondent age, marital status, occupation, qualification, attitude to travel, attitude to home and home location, reason for moving home and choosing new home location, relative levels of mobility, and dual income households.

These land use and socio-economic variables combine to generate individual energy consumption travel patterns (made up of unique journey lengths, times and mode shares). The resulting aggregate travel behaviour is hugely complex. Figure 8.1 identifies the wide range of land use and socio-economic variables associated with travel behaviour, and forms the basic conceptual structure for the research.

Figure 8.1: *Land Use and Socio-Economic Variables and Travel Behaviour.*



At times, some variables are more important than others, with the land use and transport relationship in a state of constant change. There are marked similarities here to the Aschauer (1997) crowding out debate in the economic literature field: in this case certain variables - land use and socio-economic - are traded off against each another, some overriding the importance of others at particular times and in particular areas. The temporal effect is also critically important, with the land use and transport relationship constantly changing and adapting. Previous research in the land use and transport interaction field has particularly ignored this latter dimension, typically examining just one point in time.

Hence the thesis has provided some structure to a complex field, one that can provide a way forward for future research - research that is, by nature, multi-disciplinary, covering land use, socio-economic, attitudinal, temporal and wider spatial issues. The complexity of the world no longer lends itself to research that is not multi-disciplinary. Certainly transport planning cannot be well understood without some consideration of urban planning. And urban planning cannot be well understood without consideration of transport planning.

In Chapter 3 a series of detailed research questions and themes were developed, around which the thesis research was focused. These are discussed in turn below: deliberately referring back to the debate, where it exists, in the international-wide literature and updating this with the evidence found in Surrey.

What is our current understanding of the land use and transport relationship? What about wider land use impacts that have traditionally not been considered as part of the picture?

Generally the findings are positive in tone: urban planning and form appear to influence travel behaviour in the journey to work. Generally the role of urban planning has been underplayed in reducing journey to work energy consumption. Yet, within this, there are a large number of nuances to the findings. Rather than a small number of relationships at work (such as density and travel), there are a wide range of relationships involved. Hence we should widen our lense somewhat in looking at the land use and travel debate. Also the analysis segments the relationship in various ways, by land use or socio-economic characteristic, and by type of resident or trip. Hence the traditional view of urban planning that 'one version for all' is satisfactory, becomes somewhat outdated. The impacts of acting within the urban planning field to reduce travel are likely to fall very differently on different aspects of the population. Society is richly complex, and so should be our understanding of the rationale or logic behind it.

For example, the following findings are evident (and we should again note that these findings are based on journey to work analysis rather than all trips):

- Population density: an inverse relationship is found between residential population density and energy consumption: lower residential population densities are associated with higher energy consumption patterns, and higher densities with lower energy consumption patterns, in the commute to work. Housing located in wards with the highest densities (over 35 persons/ha) is associated with 29% less energy consuming commutes than the sample average. Hence the Surrey data supports the original Newman and Kenworthy thesis, but with certain caveats. A detailed analysis is provided within the analysis of travel behaviour, considering journey length, time, mode share and energy consumption - and from this we can see that much of the difference in energy consumption is due to journey distance. Importantly, the land use and energy consumption relationship varies greatly if different definitions of density are used:

workplace population and employment densities show no similar relationships with travel behaviour.

- Population size: reflecting the Banister (1997a) threshold debate, households located in towns (and rural areas) in Surrey, below a threshold of 25,000 residential population size, are associated with high energy consumption patterns. There is however more subtlety within the evidence: there is much variation within the towns above the 25,000 threshold, reflecting the complexity of commuting possibilities in Surrey. Journeys to workplaces in London are a very distinctive cohort: relatively lengthy and typically by rail. Journeys to Outer London and other adjacent counties are high energy consumers. Journeys to the 7 key towns in Surrey (including Guildford and Woking) are the lowest energy consumers. Wider factors, such as household income have an important impact on the expected land use/transport relationship. As they increase in importance (i.e. larger incomes and greater car availability) then the expected effects of location are 'crowded out' and become less important.

- Distance from London: increased residential distance from London is associated with higher energy consumption, reflecting the general findings of, for example, Spence and Frost (1995), Banister (1992) and Naess (1995) for varying central urban areas. Within Surrey, residents living over 60km from London consume on average 91% more energy in their journey to work trips than residents living 20-30km from London (1998 data). There is no plateau in energy consumption as distance from London increases.

- Distance from strategic road network: households located close to the strategic highway network are associated with high energy consumption patterns: the A31, A3, M25 and M3 all contribute to lengthy commutes by car. Reflecting the initial findings of Headicar (1997) in Oxfordshire - but using a different level of analysis - better access to the strategic road network in Surrey extends the distance that can be travelled in a fixed time of around 45 minutes. The strategic analysis in Surrey shows that resident locations within 3km of the uncongested M3 and A31 are associated with commutes consuming 44% more energy than resident locations > 3km from the strategic road network. Journey to work distance and mode shares contribute to these trends.

- Jobs-housing balance: the conventional viewpoint in the literature is that the mix and balance of land uses affects the separation of activities and, in part, determines travel behaviour. Much of the available research is from the US (Cervero, in particular 1985, 1989a and 1995). Little evidence is available covering the UK experience. Within Surrey, households located within areas with jobs-housing balance are associated with low energy consumption in the journey to work: for example, households located in the 1.25-1.5 jobs-housing cohort are 25% less energy consuming than the sample average.

The analysis also provides consideration of a number of wider - and less well-researched - land use variables. Again the results are positive in tone, leading to the argument that a wider range of land use variables need to be considered within the land use/transport interaction field if we hope to be anything like exhaustive. For example:

- Strategic urban classification: the available literature focuses on the different travel patterns associated with commuting to central cities or multiple centres. Schwanen (2001) for example describes how the deconcentration of population in the Netherlands has led to tangential and orbital travel instead of radial. Within Surrey - a London-urban fringe location - the pattern of commuting is incredibly complex, analogous to the Jane Jacobs' billiard table; or even more complex still. The county is polycentric, with Guildford, Woking, a number of smaller centres, and London competing as the main employment centres. London works a completely different employment centre to the other urban centres, attracting long distance, rail-based commutes. Simplistic distinctions, as implied in national guidance such as PPG13, that urban areas are associated with low energy consumption and rural areas with high energy consumption are not always helpful in understanding travel behaviour in Surrey. Our understanding that 'everywhere is different' calls in to question the utility of (in depth) nationally-based guidance notes operating without more locally based guidance. It certainly requires that regional planning is well developed - and well differentiated to the national guidance. The story is not a simple one in Surrey: particular urban areas/settlements perform particular niche roles within the county. Average energy consumption for households located in rural areas is 24% higher than in town centres or 13% higher than in the rest of the urban area. Radial commutes to the 7 key towns are low energy consumers (42% less than the sample average in 1998) and even more so when household origins are from the town centre or rest of the urban area. Tangential commutes to other adjacent counties, and reverse commutes, are high energy consumers.

- Local neighbourhood streetscape layout: the land use/transport relationship manifests itself at different scales. At the local level, a number of studies, mainly in the US, have looked at the impact of local neighbourhood layout on travel behaviour. Crane (1999) gives a good overview of the literature, the general thesis being that traditional grid-style development patterns are associated with greater use of walking, cycling and public transport, and less use of the private car, than suburban sprawl and cul-de-sac type developments. A number of the studies in the US have grown out of the New Urbanism movement. Kulash et al (1990) suggest that 'traditional' circulation patterns reduce vehicular motorised traffic by 57% compared to more conventional networks. The Surrey analysis provides a first understanding of these issues in the UK - within Surrey, energy consumption is lower in neighbourhood locations with neo-traditional grid street patterns (5% lower than the sample average in 1998); and higher in locations with cul-de-sac style street patterns. This especially so when the cul-de-sac streets are remote from the village/town centre: energy consumption figures here are 13% higher than the sample average in 1998.

- Public transport accessibility: gaining stronger credence as an isssue of importance in the transport planning world (see the DfT-encouraged use of Accession modelling throughout the UK), public transport accessibility is strongly related to the discussion on density, settlement size and urban areas and access to the strategic highway network. Public transport accessibility is intuitively viewed as an important influence on travel behaviour. Amundsen (1993), McInerny (1996) and Pharoah (1992) discuss the ABC location policy in the Netherlands and the much-admired - but flawed - attempt to match accessibility and mobility profiles. Similar work, in terms of using accessibility profiling, has been carried out in the UK in Hammersmith and Fulham, Surrey and elsewhere in the UK. Few attempts have however been made to test the effectiveness of such policies in terms of travel behaviour. Of the few studies to have tackled this issue, Kitamura et al (1997) finds that distance in the US from home to bus stop affects modal share. Within Surrey, the date reveals that energy consumption in the commute to work reduces with improved public transport accessibility. Energy consumption is lower for households located close to the town centre; and higher for those located further away. But again there are caveats to this: the 25-30 minute isochrone is associated with the least energy consuming patterns (13% less than the sample average in 1998). Perhaps counter intuitively, households located closer to the urban area are associated with long journey lengths, due to the tendency to commute longer distances by rail. By far the highest energy consumers are households over 45 minutes from the urban areas (consuming 23% more than the sample average in 1998).

- The final land use variable to be considered is the use of green belts. There is a separate and distinct literature field on the use and value of green belt policy in the UK. In this thesis, consideration is given to the particular dimension of the impact of green belts on travel behaviour. The main argument being that green belt provision increases journey lengths as people are 'forced' to live beyond the green belt as the urban area becomes 'filled' to capacity. Or, more likely, house prices rise within the town, forcing people to live further afield and further from workplaces. Authors such as Elson (for example 1993, 1998 and 1999) and the Town and Country Planning Association have long argued that the current role of green belts should be re-examined. In terms of green belt impacts on travel behaviour patterns, Headicar (1997) points to evidence in Oxfordshire that - peversely - car use rates would be lower from new housing located in Oxford's green belt, than in the country towns as designated in the Oxfordshire Structure Plan. Within Surrey, green belt policy is also associated with increased energy consumption patterns. Energy consumption is lowest for households in the urban areas, rising markedly for those in the green belt and particularly for those in locations beyond the green belt (the latter 30% higher than urban locations in 1998). Hence, a further complication is at work - green belts, beneficial for other environmental reasons, at times have an adverse impact on commuting patterns. Clearly a trade-off needs to be made in terms of sustainability objectives, between the environmental benefits of green belts versus the increased emissions, energy and congestion they may bring. At the lowest level, consideration of green belt effects has to be factored into land use/transport interaction research.

A number of further points can be made concerning the land use and travel behaviour relationship. Our improved understanding in Surrey suggests that there is a wide range of land use factors which are traded off against each other. Many land use variables are significantly associated with journey distance and energy consumption. There relative importance manifests itself differently at different scales of analysis - from the individual up to the aggregate level.

Breaking the data down further, we can see that a number of cohorts are high-energy consumers. Most of these are associated with long distance Outer London or adjacent county commutes, often as 'tangential' suburb to suburb commutes. These journeys are typically poorly served by public transport.

Conversely, low energy consuming groups can be identified. Most of these low energy consuming groups are associated with typical radial commuting patterns towards the key towns in Surrey.

These types of trips are typically well served by public transport. The policy implication is that development should be focused in the 7 key towns in Surrey, but also that tangential public transport links should be the focus of investment (certainly with regard to reducing energy consumption in the journey to work).

Regression analysis tells us that the full range of land use variables considered in this analysis, when considered together, explain 9% of the variation in energy consumption in 1998 and a similar amount in 2001. So, the explanatory power - of land use influences on travel behaviour - is limited until we consider socio-economic variables as well. The most important variables, accounting for most of the change in energy consumption, are distance from London, public transport accessibility and residential population density.

The explanatory figures (R^2) may appear to be low, but when considered over a large area – for example in a county as large as Surrey; or a region as large as the South East – mean a significant change in the number of vehicle kilometres (and resulting megajoules of energy consumption). Also, urban planning is also something that can be changed - it is a policy option that we can manipulate over time. In areas of new development this change can occur quite rapidly. In addition, as we have seen, when the joint influence of land use and socio-economic variables are considered, the explanatory factor rises markedly. So the conclusion is very positive - we should be using urban form - in its various guises, from the strategic to local levels - to influence future travel behaviour and enable greater sustainability in transport (at least in the journey to work). The urban planning tool has been hugely underplayed in efforts to achieve sustainability in transport. As part of this, we can positively address global sustainability objectives, and improve the way we live our lives in our towns and cities. We however require much more concerted action than has occurred in recent years in terms of designing urban form in a manner that supports and enables sustainable transport, and this is particularly so in suburban areas.

What is our current understanding of the socio-economic and transport relationship? What about wider socio-economic impacts?

The literature covering socio-economic influences on travel behaviour is substantial in its own right. Stead (1999) gives a good summary of how socio-economic factors may affect travel patterns. The socio-economic factors most often associated with travel behaviour changes are income (household and/or personal), car ownership, work status, gender, age, household size and number of children, and educational attainment. The following findings are evident from the wide-ranging and comprehensive review in Surrey:

Household characteristics

- House tenure: highest energy consumption is found in owner occupied households with a mortgage (6% higher than the sample average in 1998). Low average energy consumption, journey distance and time and (usually) low car mode shares are found in the other tenure groupings, particularly public rented, private rented and particularly employer owned households.

- House type: highest energy consumption is found in the detached houses (7% higher than the sample average in 1998).

- House size: Banister et al (1997a), Hanson (1982) and Ewing et al (1996) report some relationship between house size and travel frequency and time. Within Surrey low average energy consumption, journey distance and times are associated with houses with 2 or less bedrooms; higher energy consumption patterns, journey distance and time with 3 bedrooms or more (5% more than the sample average in 1998).

- Number of children: there is no clear linear relationship with commuting behaviour in Surrey, however average energy consumption is lower for households with 3 or more children (11% less than the sample average in 1998).

- Car availability: within the literature there are differing views, Hanson (1982) states that trip frequency increases with car ownership, whilst Prevedouros and Schofer (1991) perceive that car ownership does not explain the variation in trip frequency. In Surrey there is a clear linear relationship - increased car availability is associated with higher energy consumption. For example, households with 2 cars consume 19% more than the sample average in 1998. Households with 3 cars and over consume 49% more than the sample average in 1998.

- Company car ownership: in Surrey access to a company car is associated with high average energy consumption (48% higher in 1998 than those without a company car), higher journey distance and higher car mode shares. Interestingly journey times are broadly similar between those with and without a company car.

- Household income: reflecting the findings in the literature (Hanson, 1982; Cervero, 1996a) energy consumption in Surrey rises as household income rises (household incomes at over £150k are associated with energy consumption patterns 35% higher than the sample average). Lower income groups also consume relatively high levels of energy and tend to be dependent on the car.

- House value: in Surrey the majority of respondents live in houses with a value less than £200k; however there is a clear mismatch with house values and household incomes. For example, 70% of household incomes are below £70k; yet only 58% of houses are valued less than £200k. The income/house price mortgage ratio limit is usually around 3/3.5, and so there is likely to be a problem of lower income groups being priced out of the local housing markets, and potentially having to travel longer distances to work than desired. Energy consumption patterns rise linearly with house value (house values between £200k-£400k and >£600k consuming at least 15%, and rising to 68%, higher than the sample average). This high energy consumption is mainly a function of longer travel distances.

Individual characteristics

- Respondent sex: the findings in the literature differ by author, Hanson (1982) reporting no difference in trip frequency by gender; Gordon et al (1989a) finding some relationship between gender and journey length. In Surrey, females have significantly lower average energy consumption patterns than males (10% lower than the sample average in 1998), a result of shorter journey distance and time. Mode share by car is however higher for females.

- Respondent age: low average energy consumption, journey distance and time is found in the youngest (17-24) and oldest (over 45) age categories in Surrey. The 25-44 age category consume 3% more energy in 1998 compared to the sample average; mainly a result of longer journey lengths.

- Marital status: the stage of life cycle appears to be important in influencing travel behaviour in Surrey. The highest average energy consumption patterns and journey distances are from those that are married/have a partner (3% higher than the sample average in 1998). All other cohorts consume less energy; most markedly single and widowed respondents.

- Occupation: not surprisingly, respondents who are employed full time are associated with higher average energy consumption than those employed part time in Surrey (8% more than the sample average in 1998); a result of longer journey distances and journey times than the part-time workers.

A further, much ignored dimension to the debate is the influence of cultural and behavioural influences. Intuitively we might feel that individuals' attitudes to travel are likely to have a large impact on travel behaviour patterns. This topic however has received very little attention in the literature, certainly within the UK. Most research has concentrated on influencing attiudes so that people might be more pre-disposed to use non-car modes of travel. A notable exception from the US is a study authored by Kitamura, Mokhtarian and Laidet (1997). This examines the influence of attitudinal (and land use) characteristics on travel behaviour for five San Francisco Bay area neighbourhoods. A similar (but broader) analysis in Surrey finds that:

- Respondents within Surrey are broadly of the following make-up: weakly pro-environment and weakly anti public transport, strong supporters of car mobility and time pressured.

- In terms of the attitude/travel behaviour relationship: as pro-environment, pro-public transport, pro-urban village attitudes increase, energy consumption decreases. Pro-suburban lifestyles and car mobility supporters are associated with high energy consumption patterns. Attitude to the environment, public transport, car mobility, time pressure, urban residence, traffic demand management are all significantly correlated with energy consumption in the commute to work. Together the attitudinal variables explain around 4% of the variation in energy consumption.

- There is almost universal support for a particular style of living in Surrey: one that involves a detached house with a garden, a garage, and a location in a rural or suburban village centre. Those dissatisfied with their residence are high energy consumers.

- The most frequent reasons for respondents moving are the perceived need for a bigger house, a change in workplace, to buy/rent a first home or a wish for a good environment. Access to transport is a much lower order factor in the decision making process. The higher energy consumers are those who deem access to a road network to be important, along with those needing to be close to family/friends, or where the price of a new home is critical.

- Where surrounding mobility is high, resident energy consumption is high (and the reverse: where surrounding mobility is low, resident energy consumption is low).

It can therefore be concluded that socio-economic characteristics are a very important part of the land use/transport debate. Within this, there is a wide range of contributory factors that underlay travel behaviour. Our improved understanding in Surrey suggests that, again, there are a number of (socio-economic) factors which are traded off against each other, with different impacts according to the level and type of analysis.

A number of socio-economic cohorts are high energy consumers (consuming 10% more than the sample average in their commute to work). These include those with high house values and household incomes and large house sizes, hence are all income related. The commuters to London act as a distinct sub-set within the data whilst, generally, the differential in travel behaviour between socio-economic groups is less than that between land use categories.

Low energy consuming groups can also be identified. Typically these are from the lower skill end of the employment market, with lower incomes and the 'retired', or those who disagree that car mobility is important.

Multi-variate analysis is important in showing the inter-relationships between a large number of variables. Regression analysis tells us that the full range of socio-economic variables considered in this analysis, when considered together, explain 28% of the variation in energy consumption in 1998 and 32% in 2001 - hence they are more important than land use variables in terms of the contributory power towards travel behaviour and energy consumption. The most important variables, accounting for most of the change in energy consumption, are household income, number of bedrooms, respondent sex, car availability, house value and company car ownership.

A critical point is that the most powerful explanatory models are found when land use and socio-economic variables are considered together - accounting for 60% of the variation in energy consumption in 1998 and 54% in 2001; and 28% of the variation in journey distance in 1998 and 32% in 2001; and 17% of the variation in mode share in 1998 and 18% in 2001 (all based on the journey to work). Hence the importance of considering energy consumption as the composite travel behaviour indicator – it is made up of a combination of travel distance, time, mode share and occupancy.

An important finding is therefore that different land use and socio-economic characteristics influence journey to work distance and mode share in different ways. Using energy consumption as a composite indicator neatly brings these travel measures together. Again the point can be made that journey to work travel behaviour is the product of a myriad of land use and socio-economic variables, hence interventions aiming to reduce the adverse impacts of travel, need to be tailored to these differences. Society is complex and so should be our attempts to assess [and ultimately] improve it.

An important issue should be re-emphasised here: the analysis in this thesis is based on journey to work data only, so does not represent all day trips, and also, because of the occupancy factor (a low car occupancy and high public transport occupancy in the AM peak), the difference in energy consumption between modes is accentuated – hence this thesis reports relatively "stronger" results than an analysis of all day data would.

What happens to travel behaviour over time? Have homes and jobs suburbanised? Have commuting distance, time and energy consumption decreased? Has car dependency decreased?

A critical and original part of this thesis has been the consideration of the impact of time. Very little research in the land use and transport interaction field has directly examined the impact of time. In the wider geographical field Harvey (1973, 2000) and Castells (1972, 1998, 1999) have written widely on the nexus of geography and history: developing a theory of spatio-temporality. Within the particular land use and transport literature, Gordon and Richardson (1991 and 1997) are perhaps the most interesting in terms of considering the temporal angle. They speculate that co-location of residence and workplace locations may occur in polycentric and even low density suburban areas. Headicar (1997) looks at the issue from a different angle: he finds that in-migration in Oxfordshire is important; with a pronounced difference in commuting behaviour between those who have previously lived in the area and those who move in - in-migrants commuting much further distances by car.

To date however there have been few attempts to systematically track individual household travel behaviour over time. Much of the other related research is based on one point in time, with little thought given to changes over time and differential change over time according to the segmentation of the population. This seems to be a major oversight.

To overcome potential problems of attrition, the Surrey analysis uses matched pair household survey analysis from 1998 and 2001. The findings from the broad ranging empirical analysis in Surrey are that Gordon and Richardson (1989a, 1991 and 1997 et al), Headicar (1997), and others, are broadly correct in their – initial and speculative - reading of events. But again there are caveats within the detail. The phenomenon of co-location does occur in Surrey, marginally and over the short term, with a periodical re-adjustment spatially of resident and workplace locations. However, within this general finding, there are a number of more specific, detailed issues:

- The individual volatility of change in travel behaviour is huge, even over the 3-year time period (1998-2001) considered. This kurtosis effect is masked by aggregate level analysis.

Disaggregating the Surrey data into 'stayers', 'outmovers' and 'inmovers' we can see that:

- The stayers: are the least energy consuming of the cohorts. However, energy consumption increases over time, by 4% from 1998-2001. This reflects trends which move in different directions - journey distance and journey time reduce by 4%, yet car mode share increases by 3%;

- The outmovers: represent the most mobile grouping in terms of journey distance travelled (4% greater distance than the stayers in 1998) have the highest car mode share (at 75%), and account for 8% more in energy consumption than the stayers in 1998;

- The inmovers: are more mobile than the stayers, but less mobile than the outmovers. They account for the greatest in energy consumption, 10% more than the stayers in 2001 (the difference in energy consumption between inmovers and outmovers is accounted for by the walk/cycle/public transport mode share more than the car mode share).

Travel behaviour therefore varies markedly by resident type, and the change over time does too. The location of new households, and the modelling of likely future travel behaviour, should recognise this likely difference in segmentation.

Considering the stayers dataset only, hence using "matched pair" analysis, a number of findings are apparent:

- In terms of density, and within the Surrey data, there appears to be an important threshold effect. Co-location in terms of travel distance and energy consumption occurs at the higher population densities. At the lower population densities, only travel distance co-location occurs, and is outweighed by the increase in energy consumption;

- Households in located in rural locations increase their average journey length and car mode share over time, meaning that average energy consumption increases by 11%. Only the households in the smaller towns in Surrey reduce their energy consumption over time;

- Households furthest from London increase their car mode share to the greatest extent over time;

- Households close to certain links on the strategic highway network - the M3, A31 and A3 - increase their energy consumption markedly, over time a reflection of higher car mode shares and/or longer travel distances. For example, households located near to the A31 consume 58% more energy than those located more than 3km from the strategic road network by 2001;

- Households in locations with good public transport accessibility (0-20 minutes journey time to the town centres in Surrey) reduce their average journey length, meaning that average energy consumption reduces by 2-4% from 1998-2001. Conversely, households in locations with poor public transport accessibility (>20 minutes journey time to the town centres in Surrey) increase their average journey length and/or their car mode share, meaning that average energy consumption increases by 6-9%;

- Households located in countryside beyond the Green Belt increase their energy consumption most over time – by 19%. Households located elsewhere increase their energy consumption by 3%;

- There is also an important income effect: lower income groups co-locate in distance terms, but this is outweighed, in terms of composite energy consumption, by increases in car dependency. The higher income groups dis-locate in terms of journey distance and become more reliant on the car, hence experience large increases in composite energy consumption over time.

Hence there are a variety of components within the co-location debate. Different disaggregations of the data reveal different trends below the aggregate level changes. Local and aggregate-level analysis is required if we are to understand the trends on the ground. Correlations analysis confirms that a number of these relationships are significant. Linear regression analysis highlights that land use and socio-economic variables account for a major part of the variation in journey to work energy consumption: 65% of the variation in 1998 and 54% in 2001.

How do we bring the land use, socio-economic and transport relationships together? Which variables play more of an influence than others? How do we quantify this? What can we learn from inferential analysis?

The world is thus a complicated place, and any attempt to simplify the land use and transport relationship into a series of statistical relationships is, to a certain extent, an exercise in aporia, i.e. an unpassable path or 'a route to nowhere'. The difficulty in understanding the complexity and subtlety should however not stop us from trying.

The general consensus is that land use is related to travel behaviour, yet there is certainly little agreement as to the extent of influence or causality. The contradictions in the research coverage might be the result of many reasons; including definitional, e.g. different measures of population or employment density used in studies; analytical, in the use of different research techniques; and indeed locational, where different geographical variables influence travel behaviour.

There are three further key issues that have run throughout the analysis and are worth discussing here.

1. The thesis seeks to develop a better understanding of what might be called the Newman and Kenworthy v. Gordon and Richardson nexus: - essentially, can land use planning play a role in reducing the impact of travel behaviour?

Both the Newman and Kenworthy and the Gordon and Richardson theses have their strong merits.

- Residential population density (as used by Newman and Kenworthy, 1989a) is associated with travel behaviour; workplace population density (as used by Gordon and Richardson, 1989a) less so.

- However, the evidence in Surrey shows that - as well as resident population density - other land use factors are also important, some that have been previously researched, others not. For example: population size, distance from London, distance from the strategic road network, jobs-housing balance, local neighbourhood design, public transport accessibility, green belt, etc.

- It is critical to consider socio-economic (including attitudinal characteristics) in the analysis of travel behaviour. Household and individual differences - such as tenure, house size, sex, income, etc. - are very influential. Socio-economic variables are more important than land use variables, accounting for a greater percentage of the variation in energy consumption. However the most powerful regression models are found when both land use and socio-economic characteristics are considered.

Interestingly Echenique (2004) develops the anglicised version of the Gordon and Richardson thesis, picking up the early lead from Breheny. Much of the difference in analysis appears to stem from differences in political beliefs, some believing in the value of public intervention; others not.

An important point to bear in mind is that integrated land use and transport planning, when implemented at the strategic and local scales, will not guarantee that everyone reduces their energy consumption in travel, but will at least give them the opportunity to do so. And at the aggregate level, sufficient numbers of people will choose to modify their travel behaviour patterns, contributing to PPG13 and wider global sustainability objectives. Spatial determinism is however limited: social influences are critically important in determining behaviour.

2. Added, and closely related to this, is the impact of spatio-temporality – what happens over time? Has co-location of homes and jobs occurred and, if so, of what type and to whom?

- This topic has rarely been considered in the literature previously. The Harvey/Castells thesis however appears helpful in the land use and transport interaction context, and could usefully be further explored beyond this thesis: the land use and transport relationship is in a constant state of change. Co-location of household and workplace location has different components within the Surrey data: As seen previously, journey to work energy consumption increases over time, by 4% from 1998-2001. But this reflects trends which move in different directions - journey distance and journey time reduce by 4%, yet car mode share increases by 3%.

- Within this aggregate level change, there are various nuances in terms of what happens at different levels of density, distance from the urban area, etc. We can conclude therefore that research that ignores the temporal angle is missing a hugely important part of the story. Likewise, policy interventions need to be based on the understanding that they are likely to have effects that differ over time.

3. And finally, the influence of scale: what might be called the Headicar versus Banister nexus – are changes at the individual level masked by looking at aggregate-level change?

- The answer here is that below the aggregate trends there is much variation. We need to understand different levels of analysis – kurtosis and aggregate effects in terms of density, population size, distance from the urban area, etc.

- In addition, there is much potential in assessing the differences in the urban from and travel relationship by resident type – stayer, inmover and outmover. Mobility differs markedly by these disaggregations.

The findings from Surrey therefore become clear: each land use and socio-economic and attitudinal variable, when considered on its own or even in small groupings, offers limited explanatory power in explaining journey to work travel behaviour. However, when a number of variables are brought together, including some variables not usually considered in the literature, using linear regression techniques, the explanatory power of the modelling begins to work. And it is these complex inter-relationships and balances between variables that are most interesting. Linear regression analysis shows that the land use and socio-economic variables, when considered together, explain 60% of the variation in journey to work energy consumption in 1998 and 54% in 2001; and [for the stayers data only] explain 65% of the variation in journey to work energy consumption in 1998 and 54% in 2001. Hence a major part of the logic behind journey to work travel behaviour.

8.3 Surrey and the South East: A Robust Integration of Land Use and Transport Planning

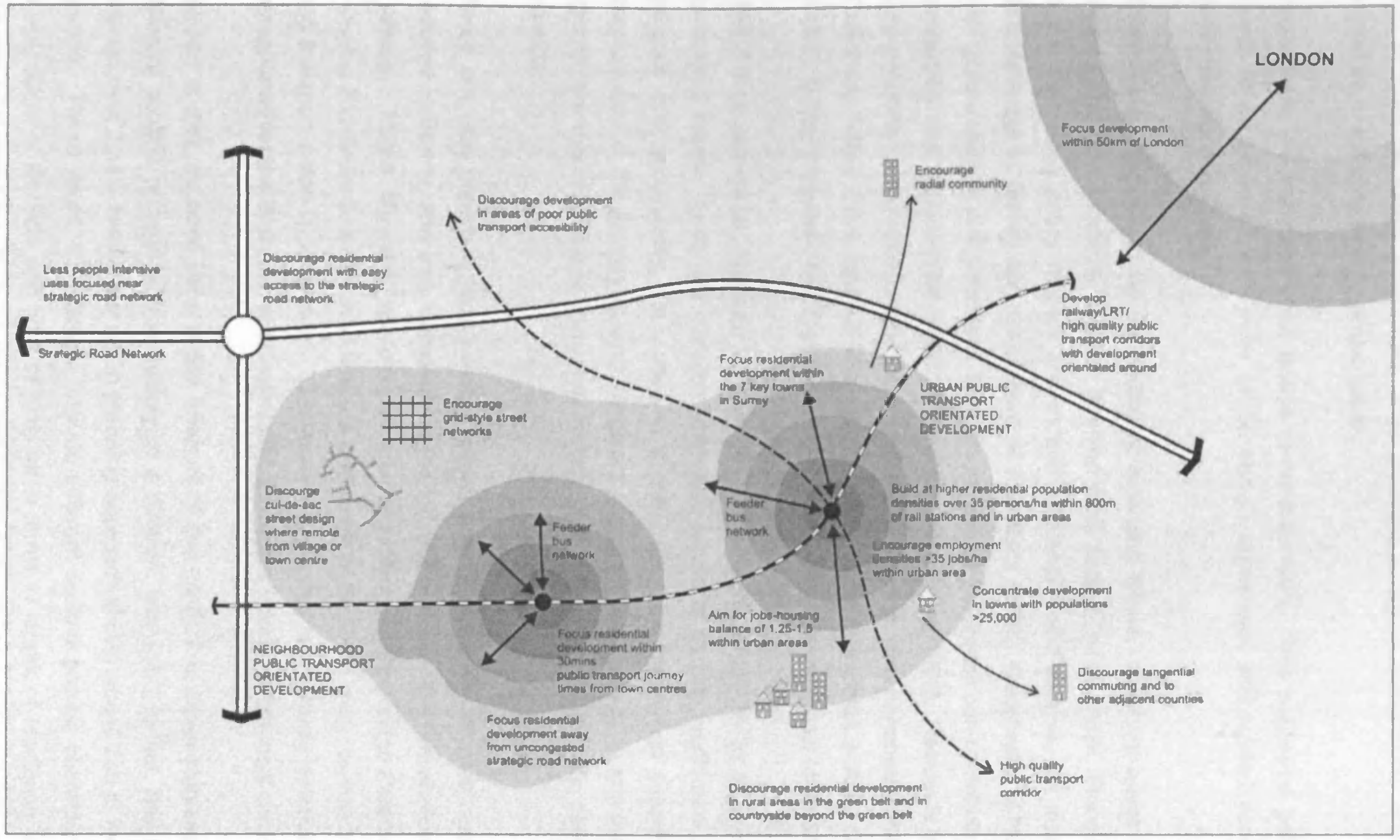
The empirical findings from this thesis should prove useful for future strategic and local planning in Surrey and the South East. The location of new residential developments will be critical to future travel behaviour patterns in the county and to the wider South East, and as a consequence, to future energy consumption patterns, emissions and global environmental objectives. They will be critical in improving the quality of urban life in Surrey. The next round of spatial strategies, local development frameworks and local transport plans hence need to explicity consider likely generated travel behaviour and propose a future optimum development form - including considerations of population density, size, location, jobs-housing balance, neighbourhood design, public transport accessibility and green belt provision. Urban form is critical to the resulting travel behaviour and can be used to help shape future travel patterns (in the journey to work at least). There is, of course, a large caveat here: the relationship between urban form and socio-economic characteristics is complex and subtle. We should keep in mind that (1) the evidence in this thesis is not based on all trip types (only the journey to work); and indeed (2) that there are other objectives to be achieved by land use and spatial planning (other than reducing transport energy consumption). One solution in terms of urban form and socio-economic characteristics is not likely to hit all objectives.

Hence differentiation becomes important. The impacts of [differential by context] urban planning policy need to be considered on different segments of society, with interventions tailored to meet different targets. From the reducing energy consumption in transport perspective, Surrey might optimally re-define itself as a new multi-centred sub-region, articulating a new spatial geography as part of the wider London and south east (and European) metropolitan region. Remember that Guildford, Woking, Sutton, Croydon, Horsham, Aldershot, Bracknell, Maidenhead, Reading and Slough, suburban south west London and inner London make up a population of over 10 million people. The size of such an area, if planned in a coordinated manner, means that we might be able to start to influence travel patterns at the regional scale. Urban planning should be able to contribute to energy and emissions reductions in the transport sector, and also help meet wider sustainability objectives and help improve our quality of life in future years. This thesis provides evidence on just one facet of this: the potential of urban planning in reducing energy consumption in the journey to work.

Again keeping in mind the above caveats, strategic planning in the South East (from the perspective of reducing energy consumption in the journey to work) should be concentrated on developing a multi-centred metropolis, based on the principles of public transport orientated development. Hall (1998) in *Sociable Cities* proposes a polycentric settlement structure for areas such as Kent, Essex and Hertfordshire, with the proposed Regional Metro for London as the building block.

In Figure 8.2, this type of regional urban planning thinking, building on Howard, Breheny, Rookwood, Hall and Calthorpe, is translated into the Surrey context. The defining structure at the regional level can include, amongst other issues, the existing (and radically enhanced) public transport network. The development pattern for Surrey can be manipulated to provide higher levels of density at key public transport nodes – hence focused polycentric development rather than suburban sprawl. Future intensified development is therefore developed around an upgraded rail network. The upgraded rail offer should include orbital and tangential options, with the Ashford-Maidstone-Reigate-Gatwick-Woking-Staines-Slough-Heathrow corridor being the focus of much improved transport investment and further development.

Figure 8.2: *Integrating Land Use and Transport in Surrey*



Critically we can move beyond a simple focus on density. We should also differentiate *between* urban areas as to which are the optimum locations for greatest intensification. This might include consideration of settlement size; appropriate balance of higher employment densities at key locations; jobs-housing balance; good public transport accessibility; residential development discouraged within easy access of the strategic road network; grid-style streets layout encouraged and cul-de-sac street layout discouraged, etc. Thus we can focus development in settlements that are currently associated with low energy consumption patterns (the existing 7 key towns and other centres within the London fringe become the focus for new housing development), and also take into account the further [integrated] urban planning structural components which are likely to be important to reducing energy consumption.

Again there are important wider issues to consider here. This suggested policy approach also needs to be balanced with wider urban design aspirations, and related economic, social and environmental objectives.

Contextuality appears to be an important emerging theme. Surrey's towns and urban areas, villages and rural locations need to develop their distinct "niche" roles. Placelessness is not an option that many policy makers and indeed residents would choose, yet many of most recent developments in Surrey are reminiscent of Kunstler's (1993) 'Geography of Nowhere'. Working with globalisation is also important. Surrey's new local geography can contribute to the new global geography: one of nodes and networks (Graham and Marvin, 1996). Residents can plug into World City networks and high-level decision making in London, simultaneously linked to New York, California, Tokyo, Paris, and the emerging agglomeration economies in Asia, South America and Africa. Surrey's location, history and quality of life provide a strong basis for this future.

The future enhanced transport system in Surrey can contribute to this contextualised and globalised future. Land use planning (including issues of density, settlement size, jobs-housing balance and accessibility, etc.), used in a more intensive manner to support reduced energy consumption in the journey to work, appears consistent with moves to improve the walking and cycling environment, public transport options and the wider urban, city design and liveability agenda.

There are also important transferability issues here. The levels of new housing development required in Surrey, and also elsewhere in the UK (for example, the Growth Areas of the Thames Gateway, Milton Keynes, Ashford and London-Stansted-Cambridge-Peterborough; and the Housing Pathfinder Areas in the Midlands and North of England) mean that an integrated planning and transport vision is paramount. The lessons for Surrey may equally be applied to these wider areas, however the approach will necessarily need to be tailored to the local context.

As part of this, we need keep at the forefront of our minds that urban planning is likely to affect different cohorts or segments in society in a different way (and, further, this impact is likely to change over time). Hence our urban planning approach should be tailored to meet these different groups. These might, for example, include different socio-economic characteristics, attitudes to travel, stage of lifecycle and type of resident in terms of length of residence (e.g. the inmovers, stayers or outmovers). Each of these different cohorts would receive a different urban planning policy approach.

In particular, there needs to be a renewed focus in tackling the problems of the high energy consumers and the stretch commuters. Some discussion is required as to whether this situation continues (a small cohort continues to consumer high levels of energy), or whether these groups are targeted to help contribute to global and UK-wide energy consumption targets. A future of regional and individual energy consumption (and/or emissions) quotas may prove to be the most effective tool - but obviously this represents a radical step from the current situation - where an overall level of consumption is set for the UK, which is also distributed evenly by area and per capita. High-energy consumers would need to buy their greater share of consumption from the low energy consumers. Either this, or engineer the situation by raising the price of travel. A combination of supply and demand side measures would in all likelihood be most appropriate.

If we can combine this type of approach within a more robust integration of land use and transport planning, then we might start to see some positive trends in terms of travel behaviour patterns. At the moment we have governmental and public debate concerning the transport sector and carbon emission targets; this is likely to widen in the future to other related issues such as energy consumption. And critically, in addition to this land use planning and transport planning focus, we need to pick up the Castells/Harvey wider social and multi-disciplinary agenda[50]. For this type of radical change of emphasis in our urban planning and transport planning practice we may need to see some form of public debate - this should be focused on achieving a consensus for the type of life we wish to live in the future: our pathways to sustainability.

8.4 Further Research Areas

This thesis has thus moved the debate forward in terms of understanding the potential for land use planning as a tool to help reduce energy consumption in the journey to work. There are however a number of future research areas which stand out as real priorities in the land use/transport interaction field. These may lead to refinements in our policy approach in urban and transport planning and a greater focus on reducing energy consumption whilst improving quality of life. There is much linkage and overlap within this simple categorisation, but important areas are outlined below. Again we should re-emphasise that land use and spatial planning has a number of objectives, not simply reducing energy consumption in the journey to work.

Potential future research, improving the evidence base for future policy refinements, might include:

- Temporal change is important yet not well understood. The introduction to this thesis refers to the history of urban form - looking back over 10,000 years - and suggests that humankind has sought to develop and improve the quality of life in towns and cities over this period. Assessments that fail to incorporate the impact of time are missing a vital piece of the jigsaw. Future research in the land use and transport interaction field can build on that developed in this thesis. A longer timeframe can be used, with analysis over time periods of, say, 0-5-10 years, assessing how energy consumption might be manipulated with urban planning and

[50] We need to move away from simplistic, single issue and 'silo thinking'. Urban development is a complex product of a myriad of factors. Binary thinking - where only a small number of factors are considered to be at work - does not really help us understand the complexities involved in understanding the rationale behind travel behaviour. The real world is complex, and so should be our analysis of it.

socio-economic interventions. It will be important to understand the importance of definition here: co-location may provide different results in terms of travel distance, time, mode and energy consumption.

- The concept of different typologies of residents - the inmovers, outmovers and stayers – can be further developed and analysed in more detail. The acknowledgement that lifestyle, attitudinal characteristics and 'stage of life' all affect travel behaviour in different ways means that any attempts to reduce travel need to understand and cater for this complexity.

- The availability of the 2001 Census data, or more recent National Travel Survey data, provides an opportunity in terms of analysis. Not least may be an update of the ECOTEC (1993) research; this time with a broader remit, covering a larger number of land use and socio-economic variables and travel behaviour, using more sophisticated analysis techniques, incorporating the temporal dimension, and developing various segmentations of the data. A related issue here would be to analyse travel behaviour in the so-called edge city/urban sprawl locations in comparison to urban areas.

- This thesis has, of course, concentrated on the journey to work. Further analysis may be useful in terms of assessing the potential for using land use planning to facilitate changed travel behaviour in all trip types. There may well be important nuances in the findings when all trip types are considered.

- There particularly needs to be a clear focus in the research as to how we might achieve future global sustainabilty targets (for example reductions in CO_2 emissions, but also reductions in energy consumption, whilst maintaining improved liveability). The use of energy consumption as a dependent variable can be further pursued here. There is, at the moment, little understanding of how the future urban planning of counties like Surrey is [or is not] contributing to global agreements signed in Kyoto and Rio de Janeiro, etc. There is certainly an evidence gap in terms of the contribution of transport investment plans - found in Local Transport Plans or Regional Transport Strategies, etc. - towards sustainability objectives and emissions targets. The planning of Sustainable Communities and Housing Pathfinder areas in the UK, for example, also requires a much more rigorous evidence base in terms of the contribution that integrated land use and transport planning can make to good urban design, and also the contribution that good urban planning (and design) can make to travel reduction objectives. The South East Plan, and other regional spatial strategies, should include CO_2 and energy emissions reduction as their central premise, based on a greater understanding of ecological footprinting and carbon auditing. There are huge issues to think through, such as achieving a semblance of equity and social inclusion, both within the UK, but also globally. The challenge of growth in China, India and Africa is likely to prove very difficult for us in moving towards sustainability objectives. Reading through a typical local development framework, local transport plan or masterplan does not make impressive reading; for most of the time we are simply rearranging the deckchairs on the Titanic.

Potential policy refinements, issues we can now incorporate into urban and transport planning (again based purely on the perspective of reducing energy consumption in the journey to work), might include:

- Sustainability objectives, including energy consumption (and CO_2 emission) reduction targets, need to be at the heart of national and local policy. Investment should be targeted to achieve these objectives. Approaches such as energy consumption and carbon auditing, ecological footprinting and equitable rationing need to be thought through in detail and incorporated in an implementable manner (if this is indeed possible). Urban planning and transport strategies need to include consideration of ways to reduce energy consumption. Implementable pathways need to be developed that can take us towards these new futures. The concept of public transport orientated development, for example, can be enshrined in urban and transport planning in Surrey (and throughout the UK). This needs to move beyond a simple reliance on residential density, to include consideration of jobs-housing balance, streetscape layout and public transport accessibility, etc. The South East Plan can, for example, include a development pattern, and future intensified development, around an upgraded rail network. This particularly should include orbital options, with the Ashford-Maidstone-Reigate-Gatwick-Woking-Staines-Slough-Heathrow corridor being the focus of much improved transport investment and further development. A balanced mix of housing and jobs and permeable street layouts can support efforts to reduce energy consumption in travel, as well as other local design details.

- A number of further detailed policy changes may become important. For example, residential development in locations with good accessibility for long distance car journeys may need to be avoided. PPG13 encourages the selection of development sites with good accessibility by public transport. Although this protects access for people without cars and potentially will have a long term value as a precautionary measure, it has little effect in reducing the long distance car commutes. From this point of view, the reverse might be much more important - to avoid locations with good accessibility for long distance car journeys. Similarly, household locations in areas beyond the green belt, in areas of poor public transport accessibility, or poor job-housing balance should also be discouraged within policy guidance. Hence we might need to be more prescriptive in terms of *discouraging* certain types of development. This might best be done through regional and local urban and transport planning strategies, rather than national guidance, to include consideration of context.

- Retrofitting may become a very important concept, where sub-optimal locations are improved (e.g. with improved street layout or public transport accessibility) to help reduce travel energy consumption by residents. This approach may become particularly important in suburban areas which are typically car dependent in nature, with a difficult combination of low density suburban sprawl and poor investment in public transport.

- Dutch-style sub-regional planning, based on ABC location policy, could be developed for each of the regions in the UK. But critically we need to learn from the difficult experience in the Netherlands: top-down implementation needs to be replaced by bottom-up consensus building and the funding of improved public transport is critical: there needs to a large number of 'A' locations available for development. This means a high level of investment in public transport, especially for tangential links. A good place to start empirically is to understand the importance of, and the potential for, increasing the density and mix of development around key public transport nodes. What difference, for example, could a transport development area push, raising densities and mix of use at key nodes, make across Surrey (and indeed the UK)?

- More can also be made of contextuality and segmentation. This might work in two ways. Firstly, further thought is required as to the differential articulation of national policy. For example, the *relative* merits of different urban areas for development and transport investment in terms of potential to achieve reduction in energy consumption. Density increases should not be indiscriminate. Masterplanning will need to consider issues of jobs-housing balance, street layout and public transport accessibility, etc. as well as density. Secondly, the impacts of policy will need to be assessed in terms of likely impacts on different segments of society (and indeed the argument is circular here: a segmented policy approach will need to be thought through). The thoughts of Tiebout (1956) have been forgotten to a certain extent, but they may have something important to offer here. We need to move beyond the thoughts of PPS1 or PPG13, and further understand the differences between urban areas: and start to articulate different roles for different urban areas. This is all the more evident in suburban/urban fringe locations such as Surrey - they have received little attention in much of the urban-centric national guidance.

The gap between the public's perceived wishes and the urban renaissance policy thrust provides an interesting difficulty. Attitude surveys suggest that most people wish to live in either mixed urban/rural or rural/remote locations, in detached houses with garages and gardens. Hence, the push for more people living in denser urban areas may prove unpopular with groups other than the typical 20-30 year old cohort. The difficulty may lie in the way the question is phrased: "*Do you wish to contribute to the protection of the environment, live in a vibrant local community, with good public transport services and easy access to good local facilities and entertainments*?" may prove an attractive choice. A strategy for selective concentration and public transport nodes may prove the optimum solution in the suburbs, and also serve to renew suburban/urban fringe communities. We should however be much more aware of the attitudinal angle in urban and transport planning.

Also, in our research and practice, we should be aware of the likely implementation gap: even assuming a perfectly clear understanding of the land use and transport relationship, the problem of effective implementation is always likely to remain. We should use future research to further evaluate the obstacles to achieving reduced energy consumption in the transport sector, policy packaging and policy pathways, etc. hence reducing the opportunity for inertia and unintended effects.

So it seems that we still need to improve our evidence base and the linkage between research and practice in the land use and transport interaction field. Patrick Geddes' (1915) thoughts are still relevant in today's world: detailed analyses of trends on the ground are ever important - the survey before plan - assessing the changing interactions and relationships found at the local and regional levels is still required. Urban form and transport behaviour are constantly changing metabolisms and we really need a better understanding of this, if we expect our policy interventions to have desirable impacts.

A major inter-disciplinary research effort may be required at the national and regional levels, incorporating many of the above themes (perhaps funded via a Royal Commission or Research Council). A research brief might seek to assess how a revised urban planning approach could best contribute to a sustainable transport future; and how a revised transport policy approach could best contribute to quality in urban design and improved liveability. This would require a more rigorous understanding of the multi-disciplinary evidence base, including the urban planning and transport fields (and potentially wider). It would also suggest that, rather than planning in the same way for all, we might start to target particular segments of the population for particular action. The global environmental and liveability agendas, in particular, demand that we make a huge leap in our conceptual thinking here.

The absence of this type of analysis means that, at the moment, the combined effects of land use and socio-economic impacts are not given sufficient weight in the search for reduced car dependence. We have only an early understanding of how the disparate disciplines of urban planning and transport planning can work well together, of the benefits of integration, of likely synergies. To reiterate, we have little idea as to how investment priorities - in Sustainable Community Plans, Growth Area Studies, National Transport Strategies, Regional Transport Strategies and Local Transport Plans, together with Regional Spatial Strategies, Local Development Frameworks and many local masterplans - will contribute to energy consumption targets and global sustainability aspirations. This seems to be a major oversight. Not surprisingly, our collective poor understanding of such a critical part of the urban development picture means that efforts to improve the sustainability of and quality of life in our towns, cities and regions are not always working to the degree we would expect. We are, to a certain extent, stumbling blindly into the future.

The start to this thesis provided a quote from one of the pre-eminent thinkers in the sustainability and urban planning field, as repeated below.

"*We are only aware of the process by which our species is committing environmental suicide.*" (Castells, 1999, in The Castells Reader, Ed. Susser, 2002, p.376).

We now need to move on apace. Travel behaviour patterns have changed exponentially in recent years; yet our understanding of them, the rationale behind them, and our tools to manage travel demand have not. Castells asks that we emerge from the labrynth of ideas in the urban planning field. In terms of integrated urban planning and transport planning we are one step behind - we need to further develop our theoretical understanding of evolving trends on the ground (and, at the same time, continue to implement our best known means of achieving reduced travel demand). Current urban planning practice, particularly in suburban areas, tends to increase traffic volumes by dispersing activities and hence facilitates private car travel rather than that by public transport, walking or cycling. Public transport orientated development as an evolving practice tends to be focused very much on urban areas and does little to differentiate between urban areas or consider issues beyond density.

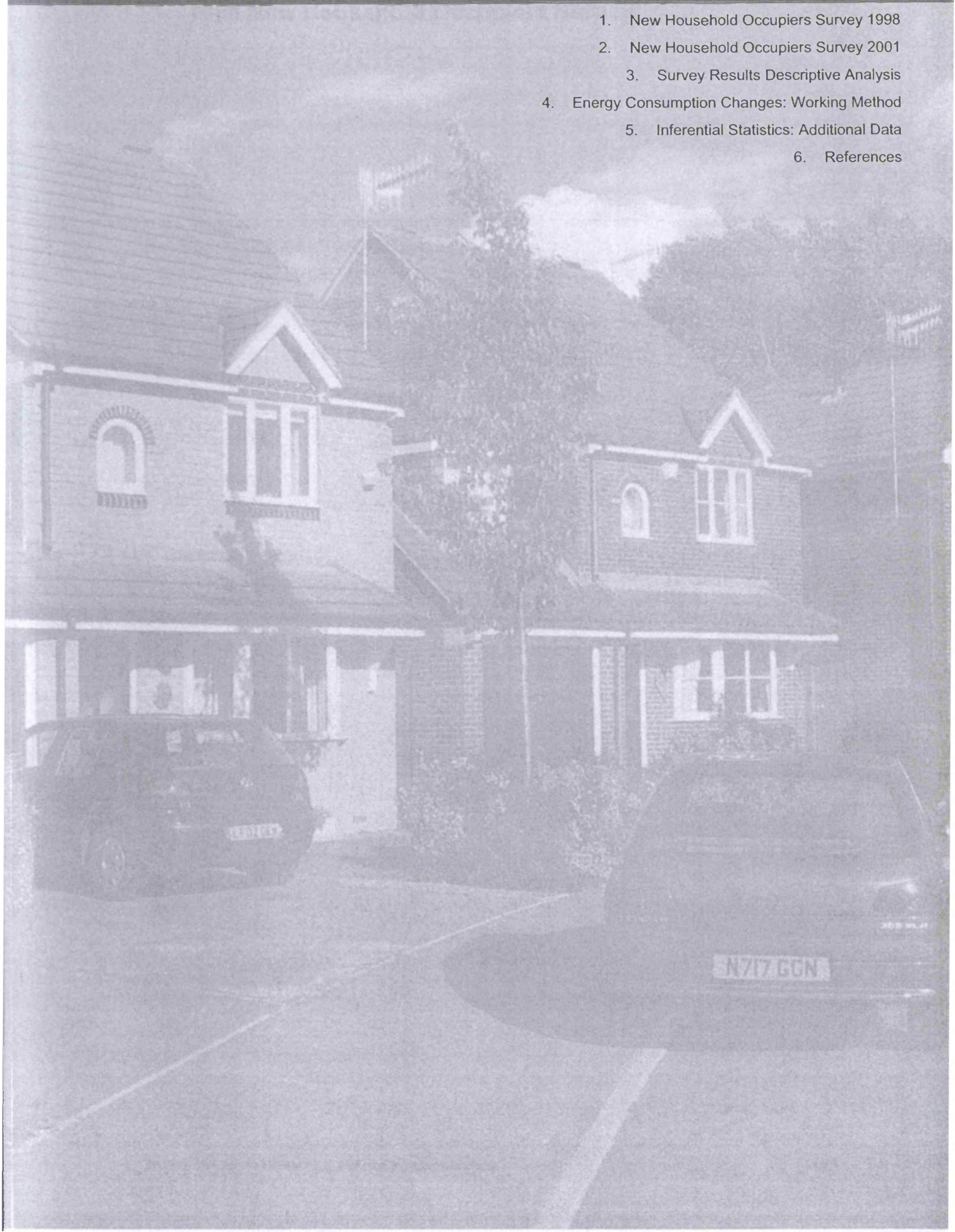
Achieving sustainability and liveability objectives need to be at the heart of changes in urban and transport planning. A new, differential spatial geography may be required (for example, for Surrey as part of the wider London and southeast region) and as part of a wider social, economic and environmental change agenda. The future intellectual debate - concerning the integration of land use and transport planning - is thus centred on the contribution that can be made in terms of improving sustainability and liveability.

The conclusion reached is that integration requires action across a wide range of fields. New households, for example, should be located in a coordinated manner in relation to the density of development, settlement size, distance from urban centres and transport networks, jobs and housing balance, local neighbourhood design, public transport accessibility and green belt designation. Ad-hoc "pepperpotting" of new housing development no longer remains an option. Through "smart growth" strategies, reduced transport energy consumption (in the journey to work at least) might be better enabled; and transport sustainability achieved in the location of major new development.

The evidence presented in this thesis suggests that land use planning is an important part of the toolkit here; that the strategic and local structure of urban form can help us move towards reduced energy consumption in the journey to work. In our research, policy making and practice we thus need to understand the importance of contextuality and distinctiveness, complexity in relationships, segmentation, temporal change and adaptation, of urban metabolism and the logic behind behaviour. Only then may we raise the effectiveness of policy interventions – and actually achieve a reduction in travel by design.

Annexes

1. New Household Occupiers Survey 1998
2. New Household Occupiers Survey 2001
3. Survey Results Descriptive Analysis
4. Energy Consumption Changes: Working Method
5. Inferential Statistics: Additional Data
6. References



Annex 1

1998 New Household Occupiers Survey

Annex 2

2001 New Household Occupiers Survey

Annex 3: Descriptive Outputs

	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
respopde	2,921	50.8	0.6	51.4	44,543.2	15.2	11.8	139.0
respopsize	2,919	8.0	1.0	9.0	21,863.0	7.5	2.0	4.1
tc	2,921	2.0	1.0	3.0	5,834.0	2.0	0.6	0.3
gb	2,921	2.0	1.0	3.0	3,565.0	1.2	0.5	0.2
houseten	2,865	6.0	1.0	7.0	5,281.0	1.8	1.4	2.0
housetyp	2,865	8.0	1.0	9.0	9,035.0	3.2	2.6	6.6
bedrooms	2,921	6.0	1.0	7.0	9,383.0	3.2	1.1	1.3
sex98	2,865	2.0	1.0	3.0	4,387.0	1.5	0.5	0.3
age98	2,865	4.0	1.0	5.0	7,026.0	2.5	0.9	0.7
marital	2,865	4.0	1.0	5.0	4,317.0	1.5	0.9	0.9
children	2,921	4.0	0.0	4.0	1,716.0	0.6	0.9	0.9
mode	2,921	7.0	1.0	8.0	12,116.0	4.1	3.2	10.5
jd98	1,653	391.0	0.0	391.0	49,743.7	30.1	26.8	718.5
jt98	1,653	288.5	0.0	288.5	69,342.9	41.9	34.6	1,196.2
ec98	1,653	1,124.0	0.0	1,124.0	99,458.6	60.1	1.5	61.8
houseval	531	2,470,000	30,000	2,500,000	162,006,950	305,098	222,820	49,648,786,641
housinco	716	6.0	1.0	7.0	2,459.0	3.4	1.7	2.9
compcar	819	3.0	1.0	4.0	1,504.0	1.8	0.4	0.1
ec01	525	394.7	0.0	394.7	30,539.8	59.4	2.3	54.9
distlon	1,808	51.5	21.6	73.1	73,972.8	40.9	11.6	134.4
caravail	459	8.0	0.0	8.0	752.0	1.6	0.8	0.6
qualific	1,064	3.0	1.0	4.0	2,280.0	2.1	1.1	1.2
occupat	2,422	2.0	1.0	3.0	3,629.0	1.5	0.8	0.7
reasch	2,865	14.0	1.0	15.0	16,011.0	5.6	4.5	20.3
reasmov	2,864	15.0	1.0	16.0	14,536.0	5.1	4.6	21.0
dfhighwa	1,625	3.0	1.0	4.0	3,113.0	1.9	1.1	1.2
ptaccess	2,869	4.0	1.0	5.0	8,143.0	2.8	1.4	1.9
jhbnew	2,921	5.0	1.0	6.0	11,583.0	4.0	1.9	3.5
ndesign	2,921	2.0	1.0	3.0	3,841.0	1.3	0.6	0.4
sex01	978	3.0	1.0	4.0	1,483.0	1.5	0.5	0.3
age01	1,103	3.0	1.0	4.0	2,875.0	2.6	0.9	0.8
attenv	595	4.0	1.0	5.0	2,301.0	3.9	0.8	0.6
attpt	595	4.0	1.0	5.0	1,555.0	2.6	0.9	0.9
attres	595	4.0	1.0	5.0	2,475.0	4.2	0.9	0.8
attmob	595	4.0	1.0	5.0	2,577.0	4.4	0.7	0.5
atttime	595	4.0	1.0	5.0	2,376.0	4.0	0.8	0.7
attuv	595	4.0	1.0	5.0	2,143.0	3.6	0.9	0.7
attpm	595	4.0	1.0	5.0	1,786.0	3.0	1.1	1.1
attwork	595	4.0	1.0	5.0	1,709.0	2.9	0.9	0.9
Surrmobjtw	2,921	4.0	1.0	5.0	6,880.0	2.4	0.0	0.9

Annex 4: Energy Consumption Changes Working Method

UK Energy Consumption

Recent changes are shown below, together with assumptions, working method and sources.

1. Energy Consumption in Million Tonnes of Oil Equivalent (Mtoe)

(From Travel Trends 2004 or Transport Statistics Great Britain TSGB 2004, both Department for Transport)

	1992	2002	% Change
Road transport petroleum (Mtoe)	39.4	42.0	6.6%

2. Calculate Petrol/Diesel Split

**%petrol/diesel for road transport: petrol 69% and diesel 31% in 1992; petrol 53% and diesel 47% in 2002 (TSGB, 2004)*

Petrol	27.2	22.2	-18.1%
Diesel	12.2	19.7	61.6%

3. Calculate Energy Consumption in GJ/tonne Using Gross Calorific Values

**gross calorific value: 1 tonne of oil equivalent (toe) = 41.87 GJ*

gross calorific values = 47.4 GJ/tonne of motor spirit; 45.8 GJ/tonne diesel (TSGB 2004)

Road transport petrol (GJ/tonne petrol)	1287.3	1053.9	-18.1%
Road transport diesel (GJ/tonne diesel)	558.8	903.0	61.6%

4. Calculate Energy Consumption by Mode (GJ/tonne)

1992 Cars = 90%.

2002 motor spirit make-up from cars = 95%, vans = 4%, M/C = 1%

1992 Cars = 10%.

2002 diesel from lorries = 68%, bus + coach = 7%, diesel cars and taxis =22% (TSGB 2004)

	1992	2002	% Change
% of petrol by car	1158.6	1001.2	-13.6%
% of diesel by car	55.9	198.7	255.5%
Sub-total by car	1214.5	1199.8	-1.2%

5. Total Car Stock (Millions)

Petrol (84%), diesel (13%), other (3%) (TSGB, 2004)

Total Car Stock			
Petrol	17.6	23.9	
Diesel	2.7	3.7	
Other	0.6	0.9	
Total	20.9	28.5	36.4%

6. Calculate Energy Consumption Change by Car

Divide by billion passenger kilometres

EC (MJ/km)			
Car	**2.1**	**1.9**	**-0.09%**

Annex 5: Inferential Statistics: Additional Data

5A. Type of Data

Variable Code	Variable Label	Variable Type
respopde	Residential population density	Interval/Ratio
respopsize	Residential population size	Ordinal
distlon	Distance from London	Interval/Ratio
dfhighwa	Distance from highway	Dichotomous
jhb	Jobs-housing balance	Interval/ratio
tc	Resident location (town centre/rest of urban area/rural)	Ordinal
ndesign	Neighbourhood design	Ordinal
ptaccess	Public transport accessibility	Interval/ratio
gb	Resident location (urban area/green belt/countryside beyond green belt)	Ordinal/nominal
houseten	House tenure	Nominal
housetyp	House type	Nominal
bedrooms	Number of bedrooms	Interval/ratio
children	Number of children	Interval/ratio
caravail	Car availability	Interval/ratio
compcar	Company car	dichotomous
housinco	House income	Interval/ratio
houseval	House value	Interval/ratio
sex	Respondent sex	dichotomous
age	Respondent age	Interval/ratio
marital	Marital status	Nominal
occupat	Occupation	Ordinal/nominal
qualific	Qualification	Ordinal/nominal
attenv	Attitude to the environment	Ordinal
attpt	Attitude to public transport	Ordinal
attres	Attitude to suburban residence	Ordinal
attmob	Attitude to car mobility	Ordinal
atttime	Attitude to time pressure	Ordinal
attuv	Attitude to urban village lifestyle	Ordinal
atttdm	Attitude to traffic demand management	Ordinal
attwork	Attitude to working time	Ordinal
reasch	Reason for choosing new location	Nominal
reasmov	Reason for moving	Nominal

Nominal: classification of observations, numbers are arbitrarily assigned

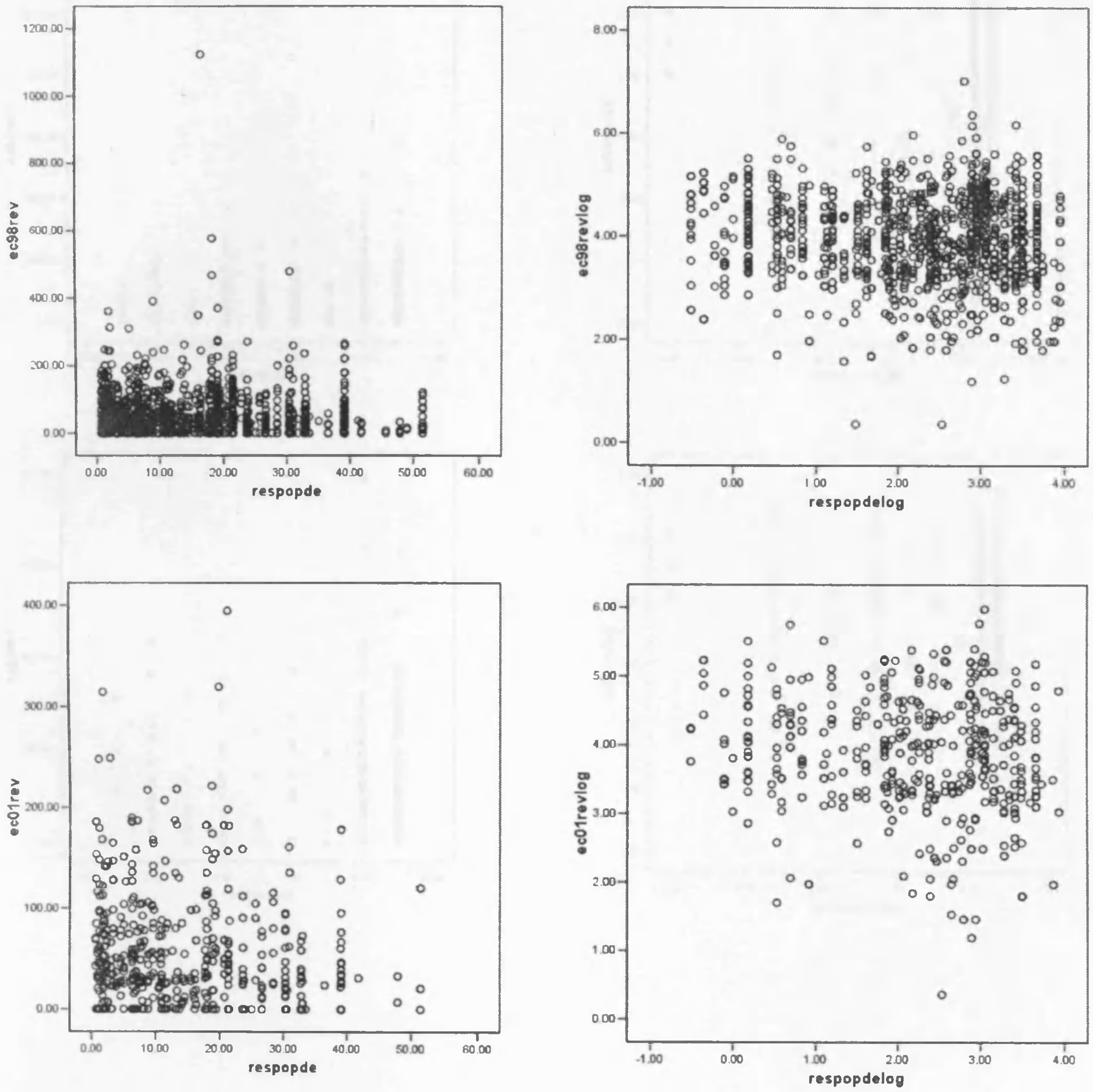
Ordinal: classification of observations, but where ranking of one observation against another is possible

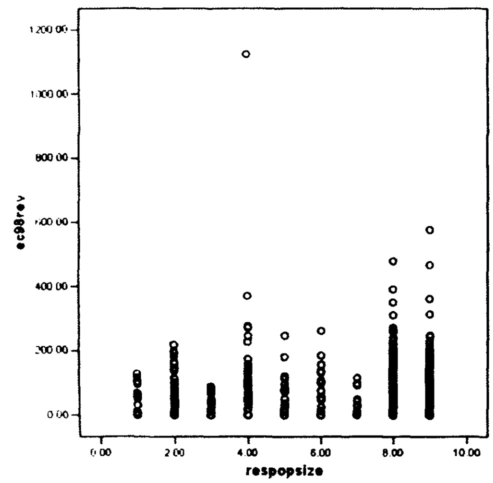
Interval: allows the sorting and ranking of observations and the establishment of the magnitude of differences separating observations

Ratio: the highest level of measurement, similar to interval but also has a known and absolute zero

Dichotomous: only two observations possible.

5B. Variable Scatter Plots (with Logarithmic Change)

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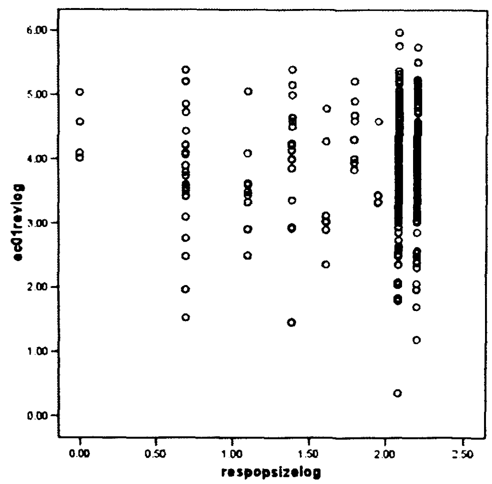
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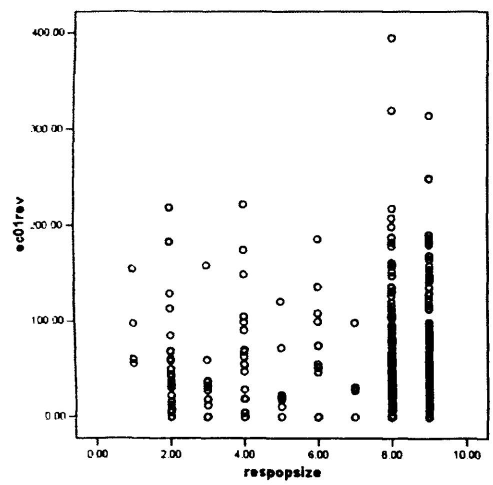
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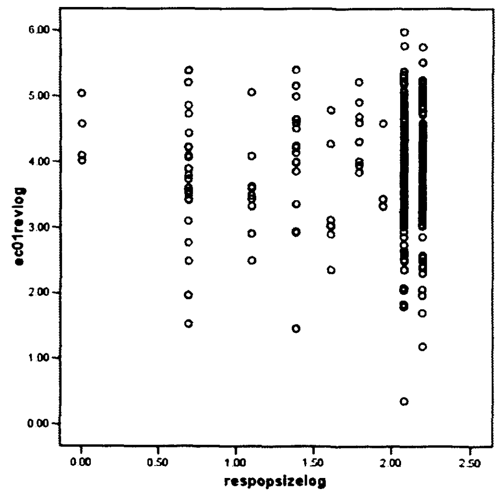
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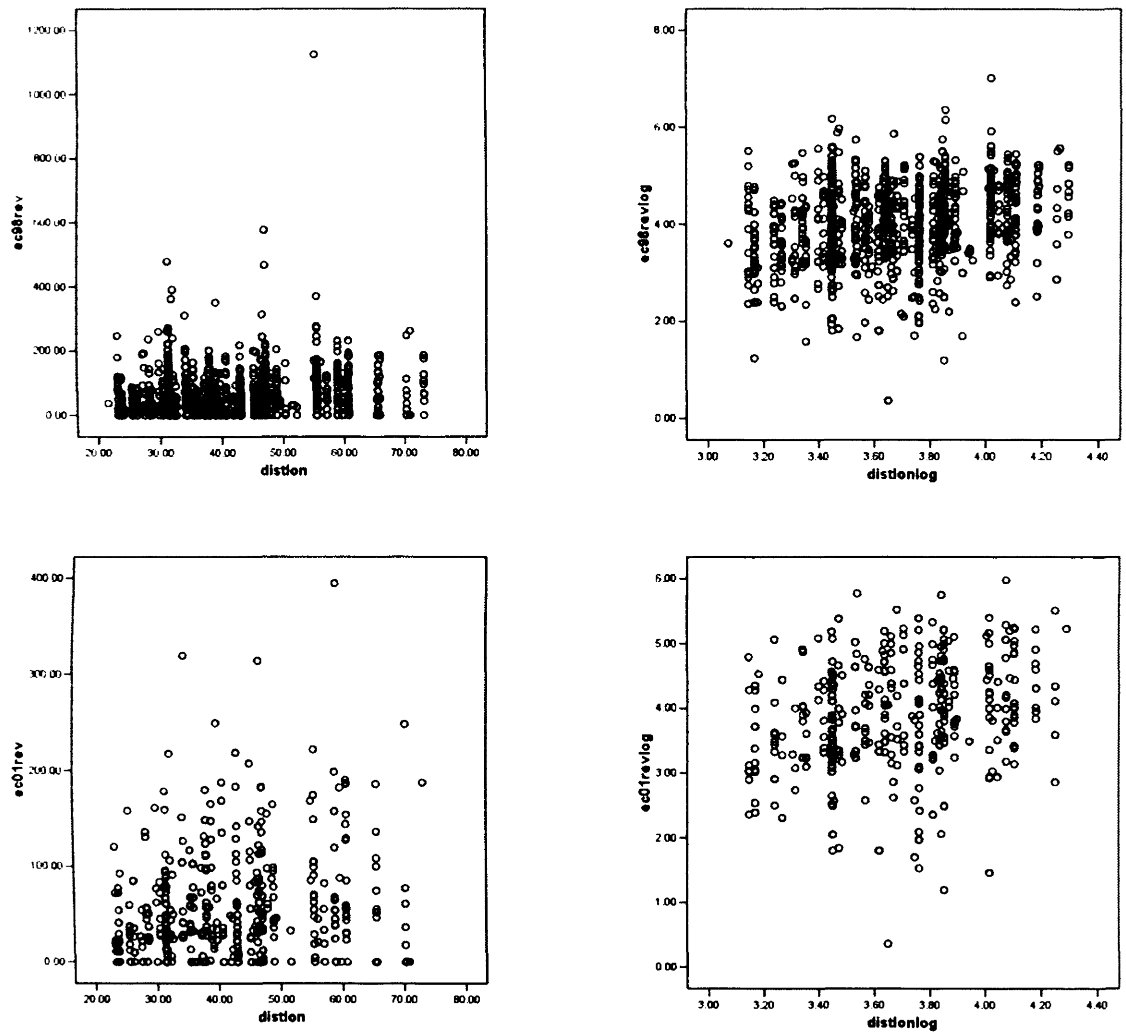
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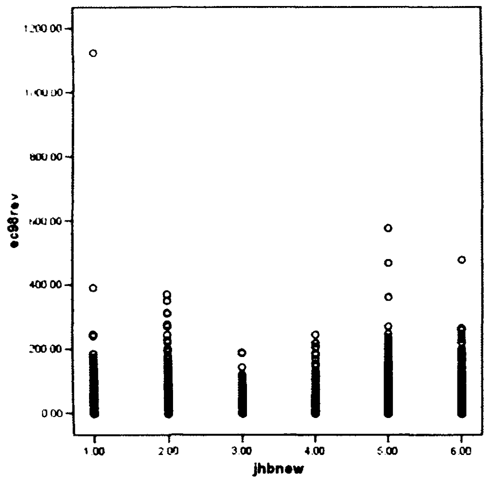
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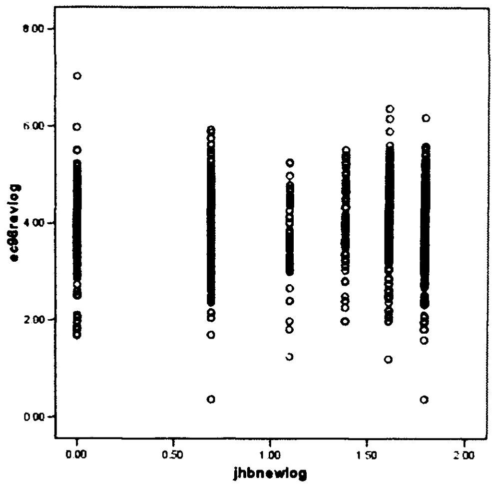
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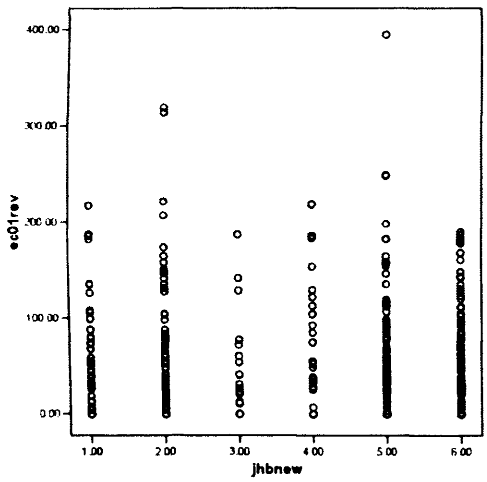
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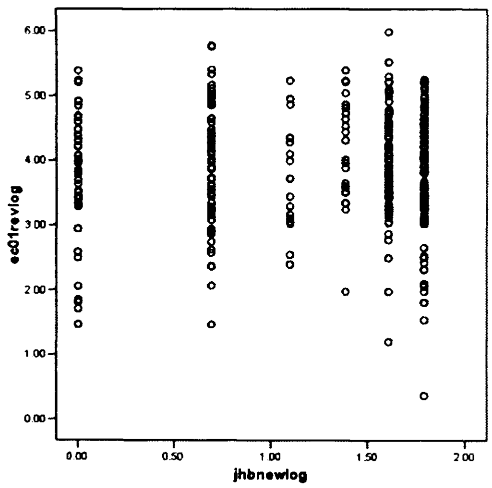
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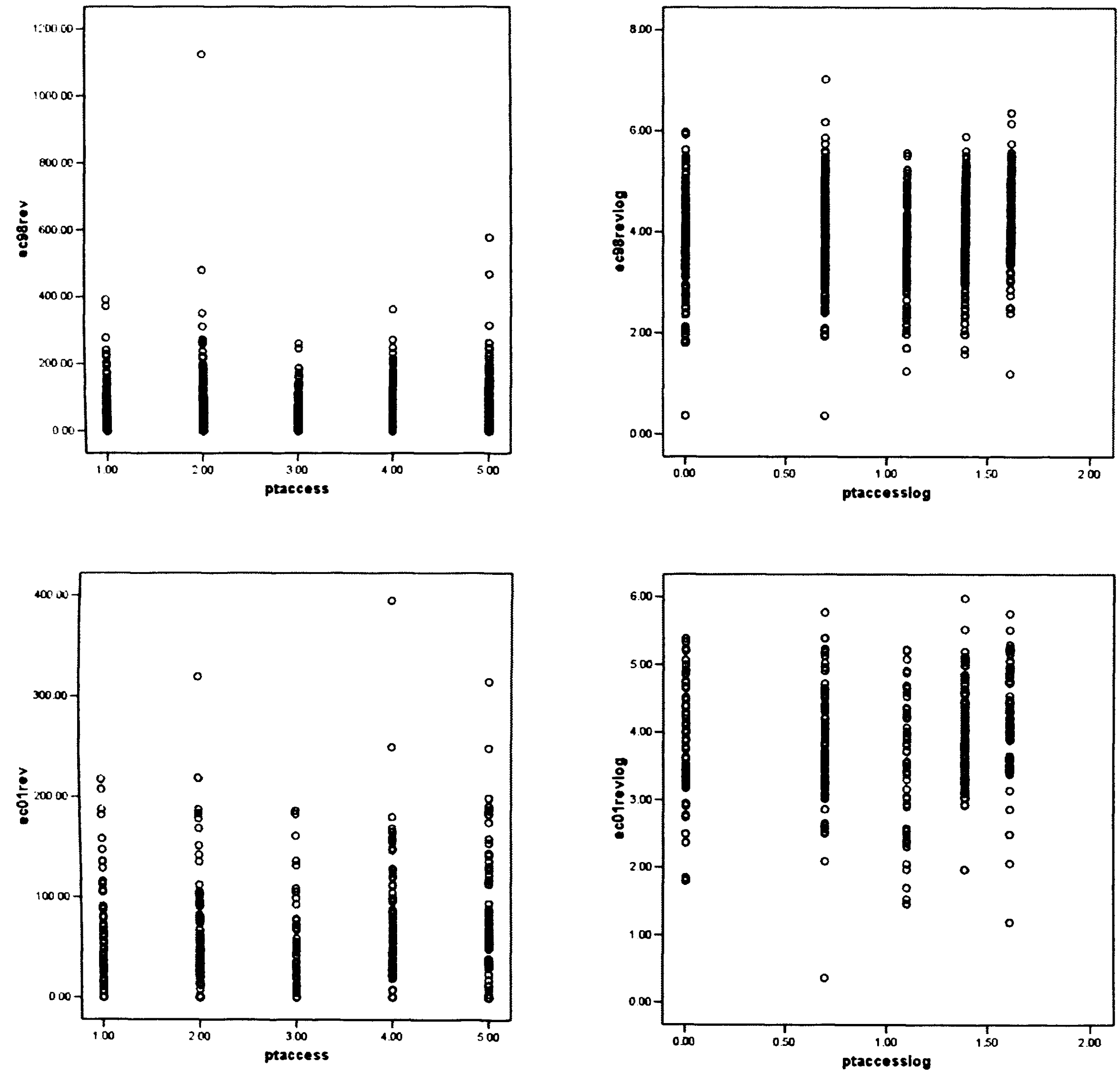
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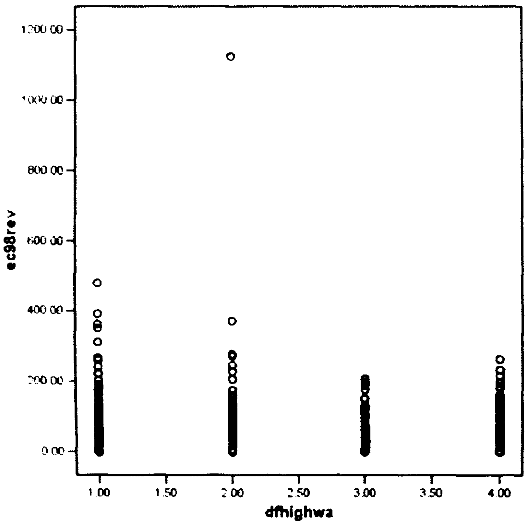
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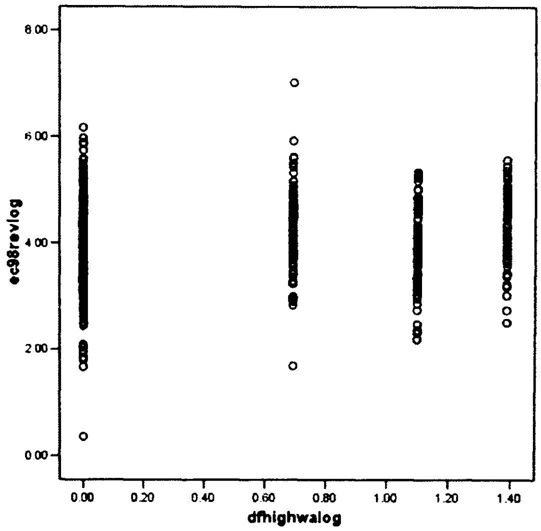
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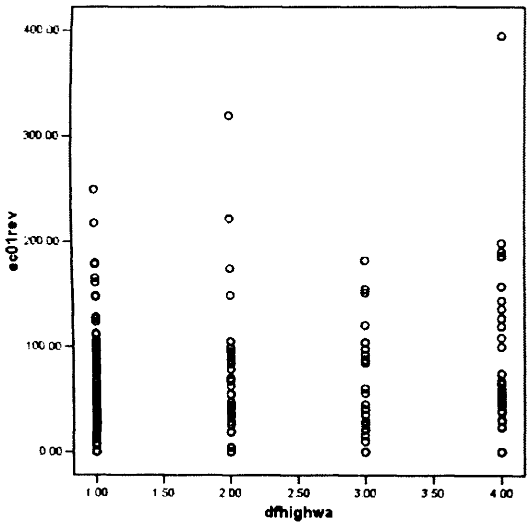
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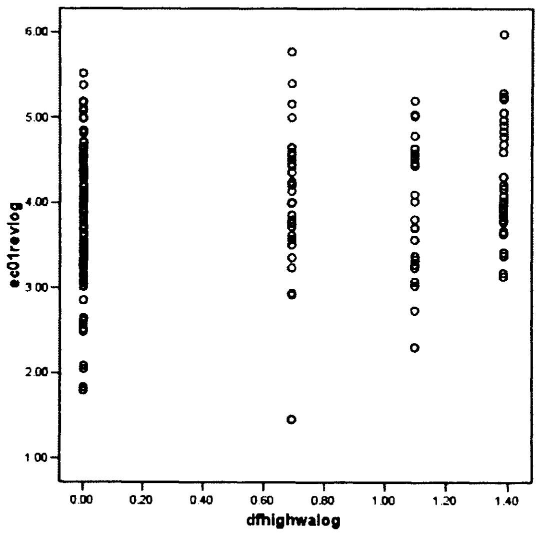
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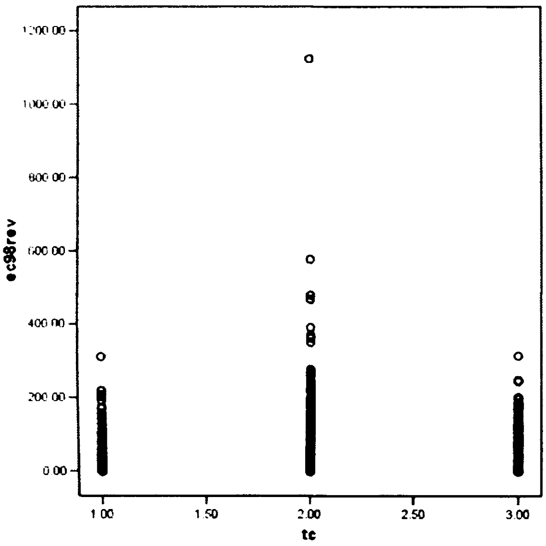
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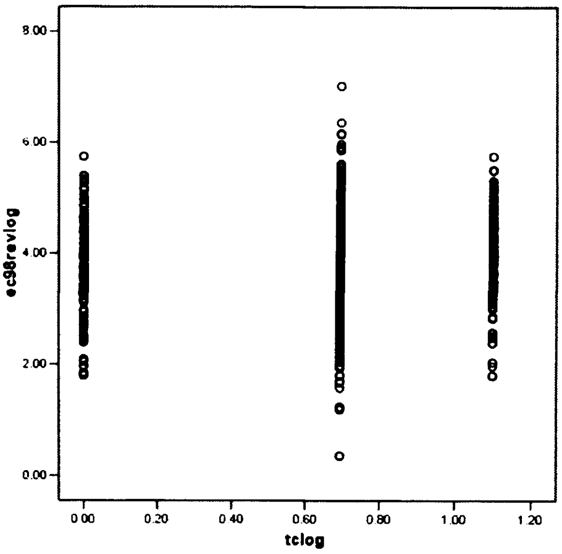
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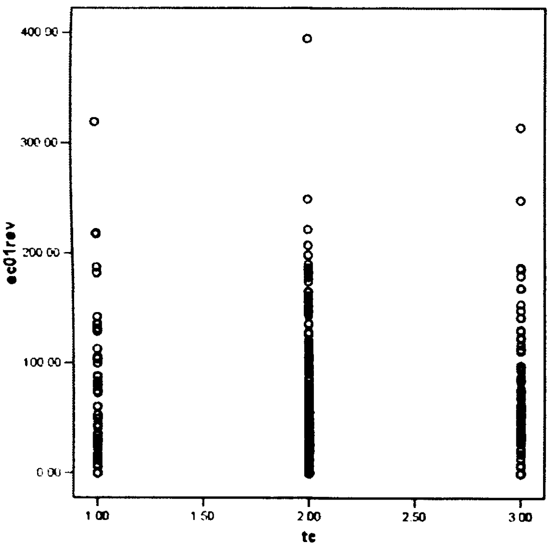
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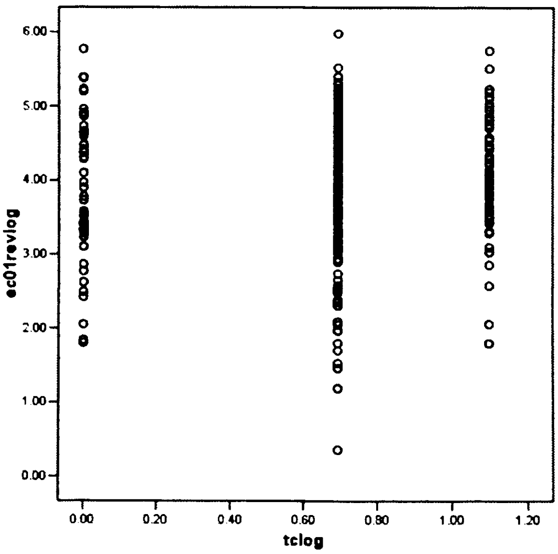
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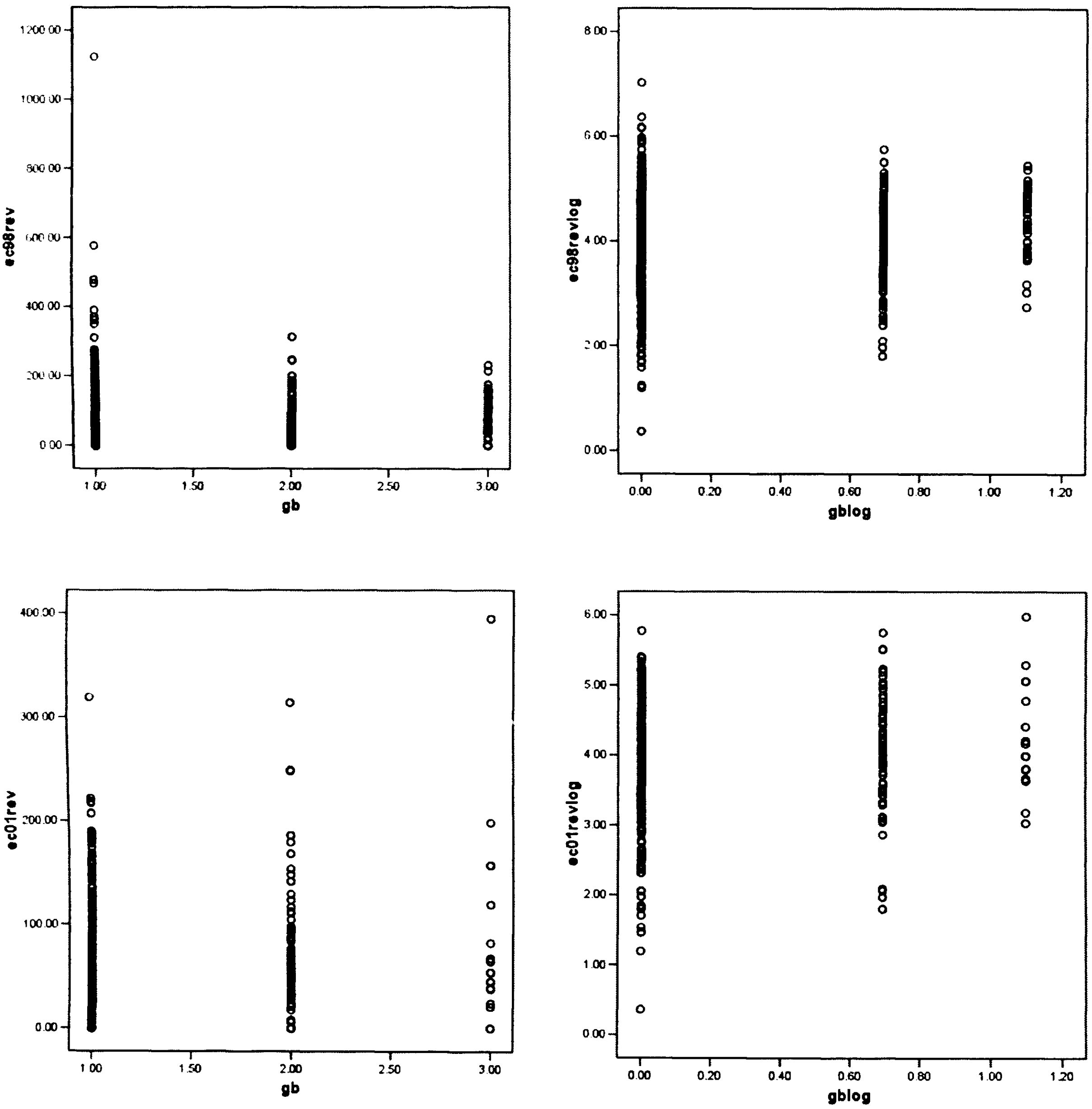
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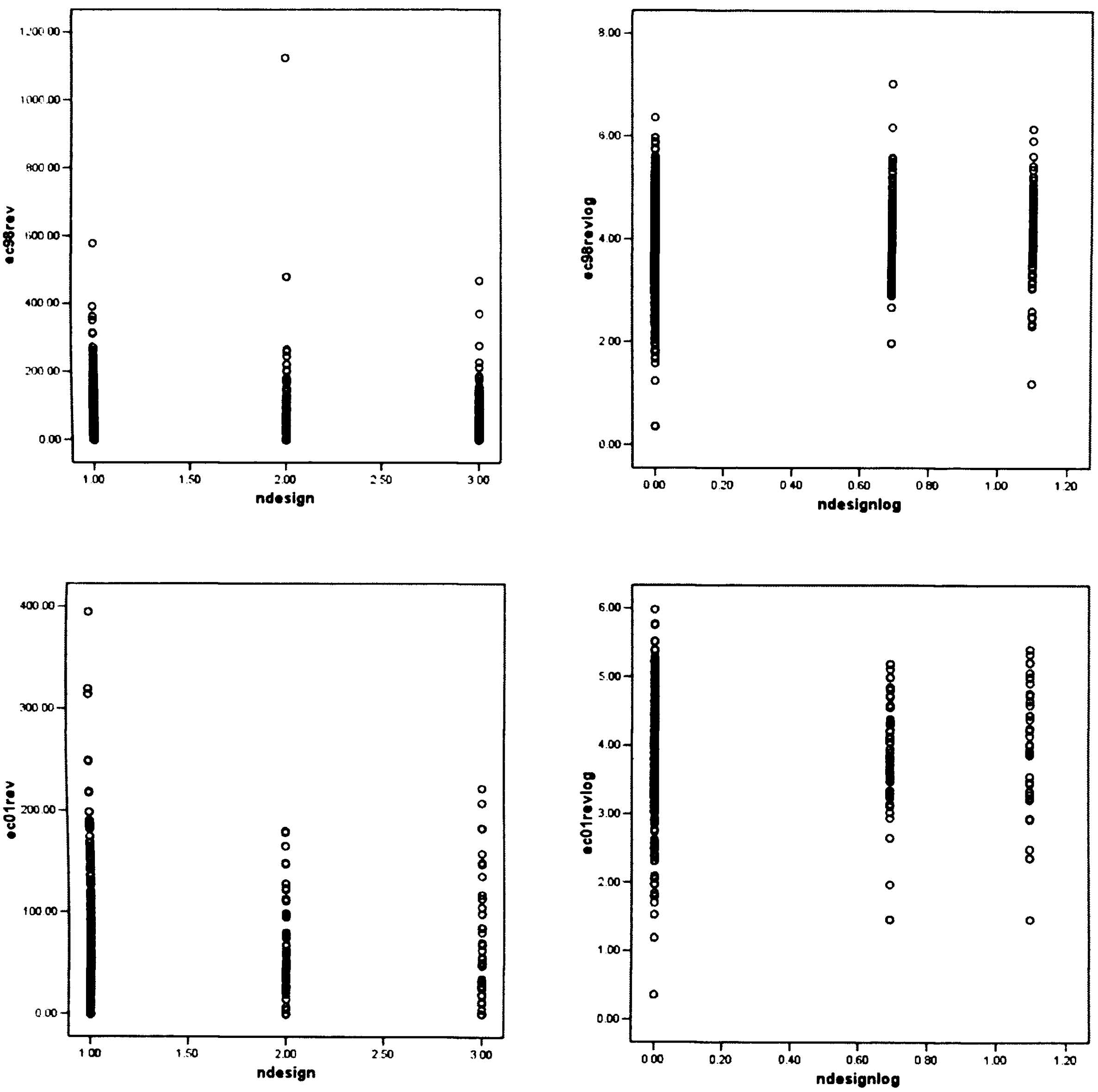
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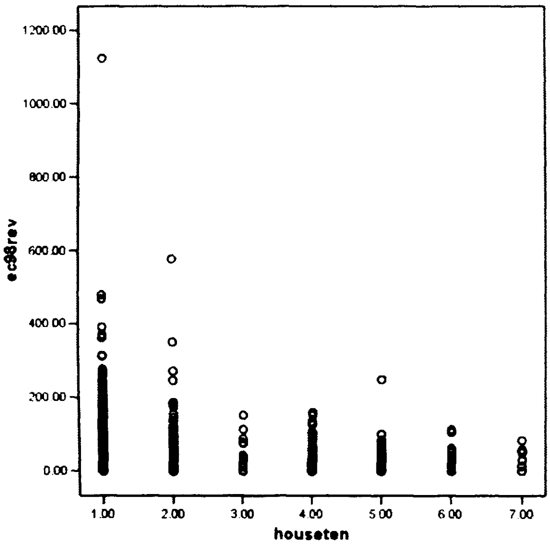
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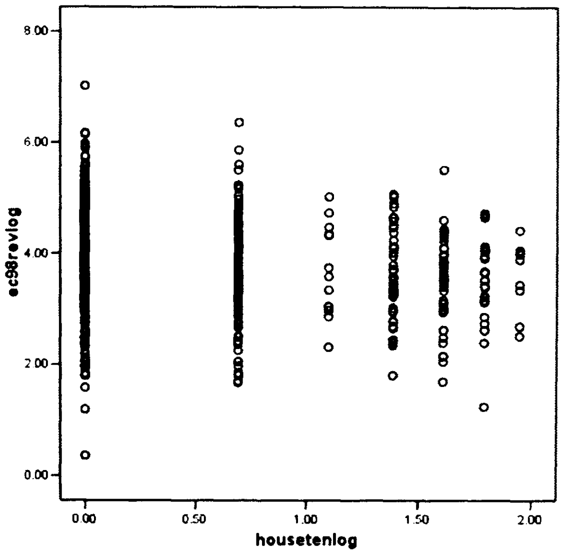
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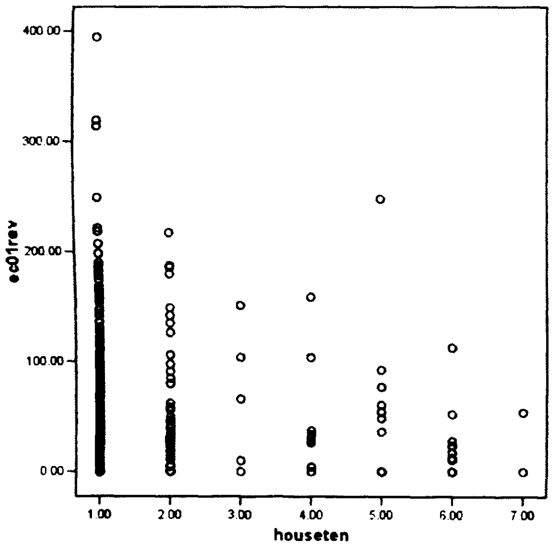
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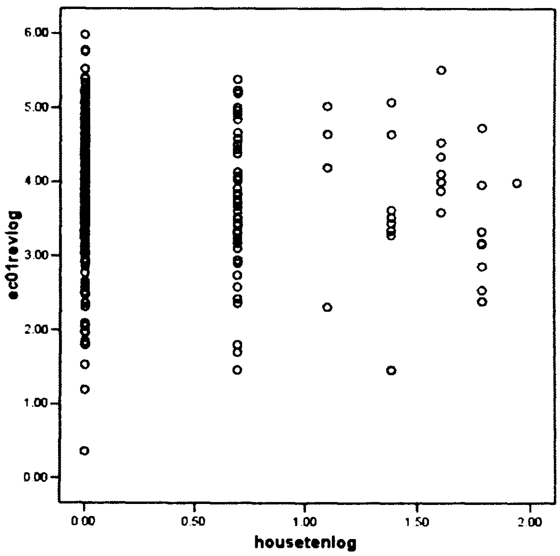
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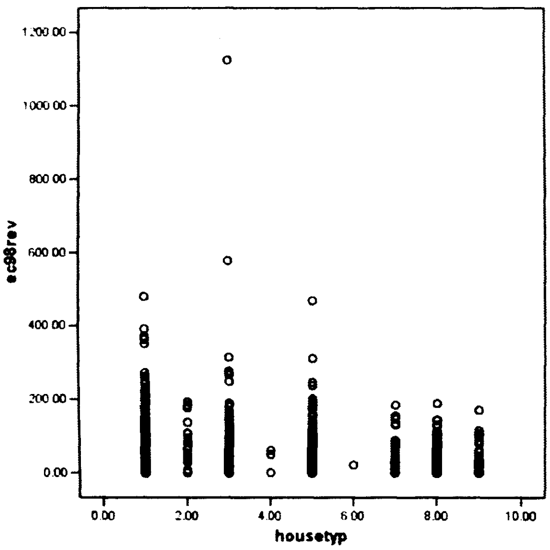
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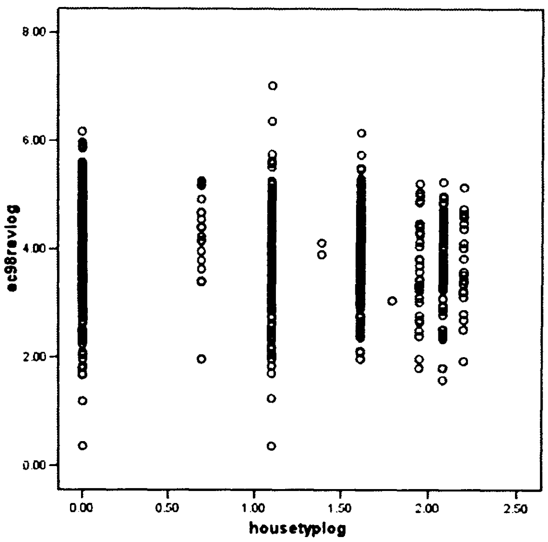
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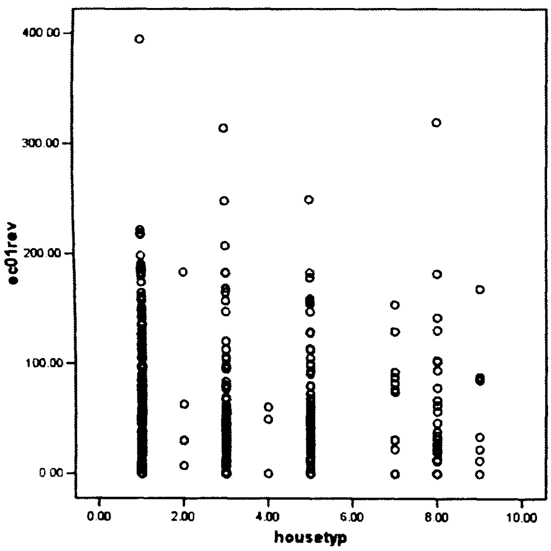
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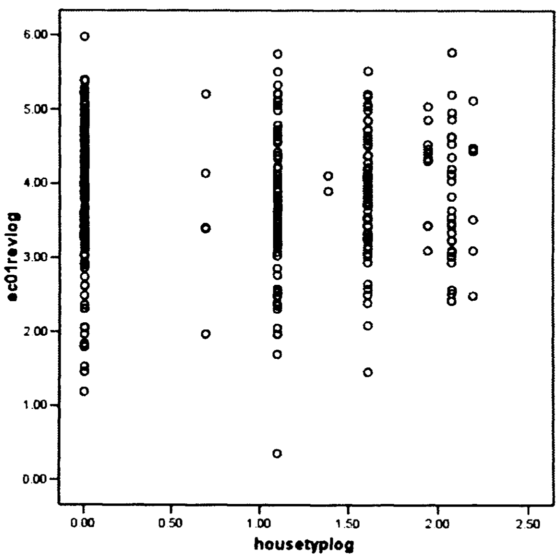
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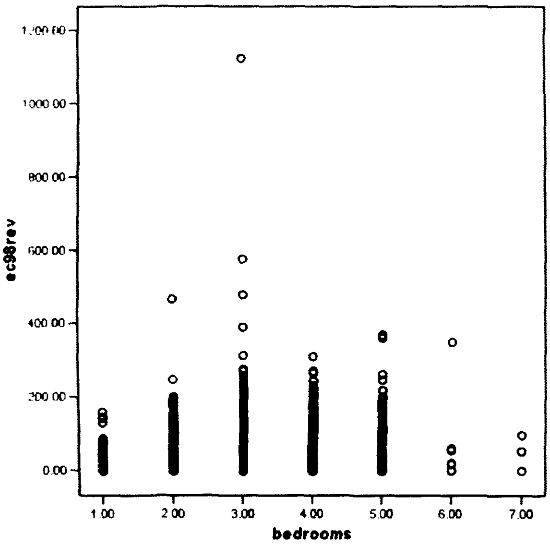
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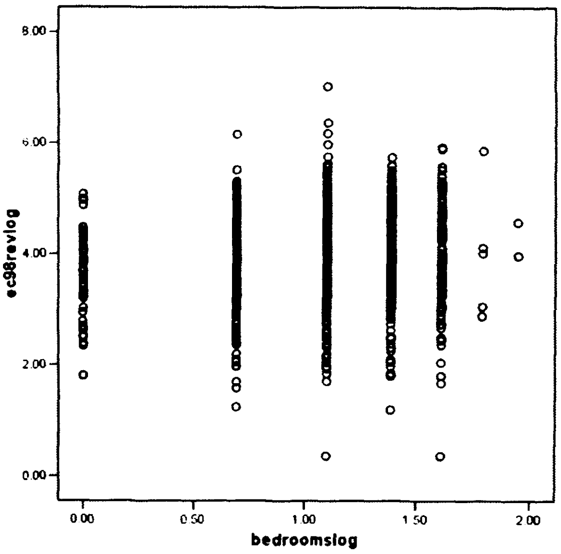
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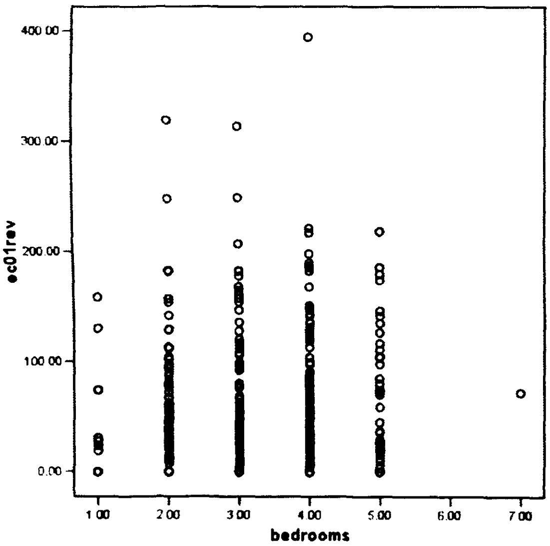
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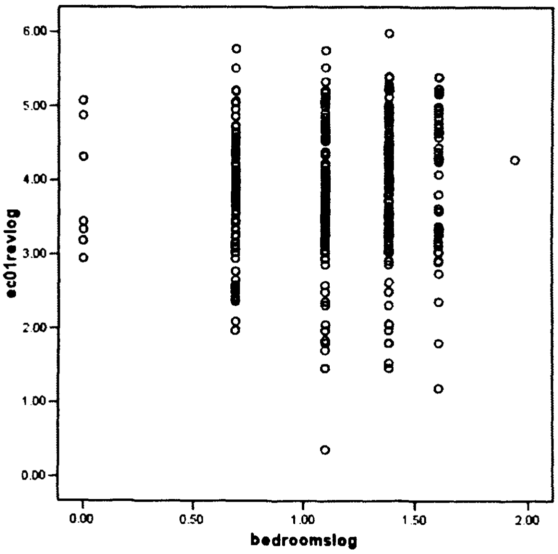
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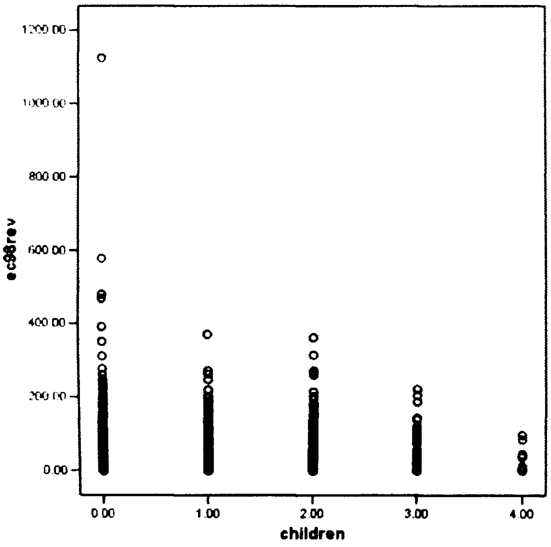
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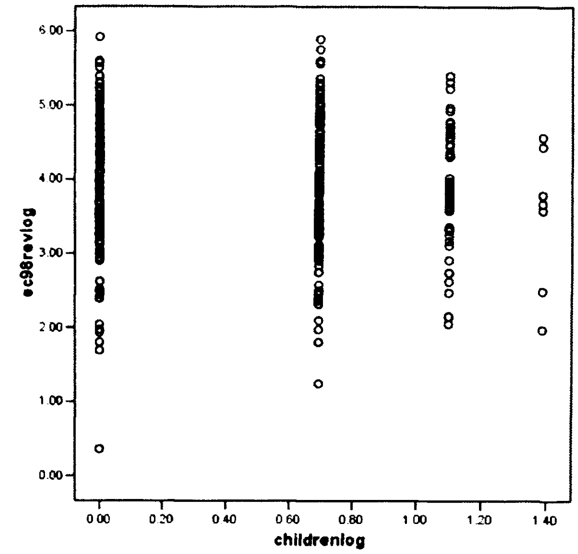
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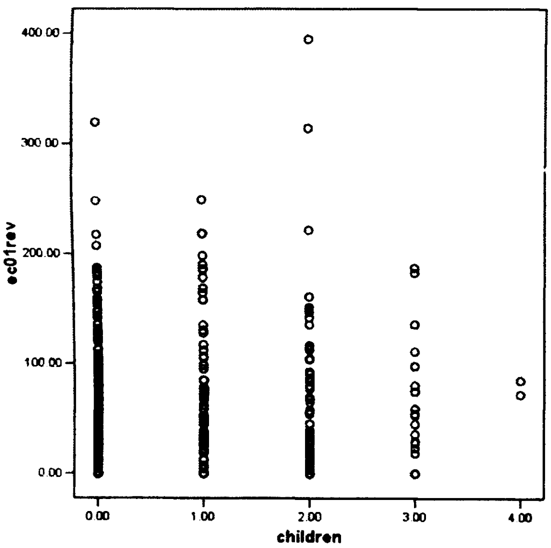
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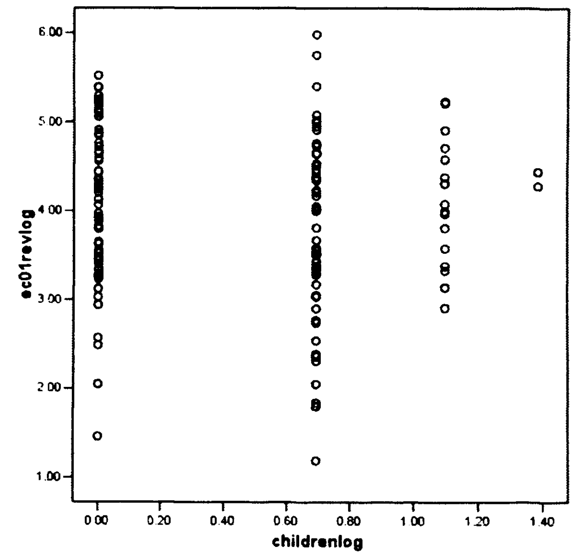
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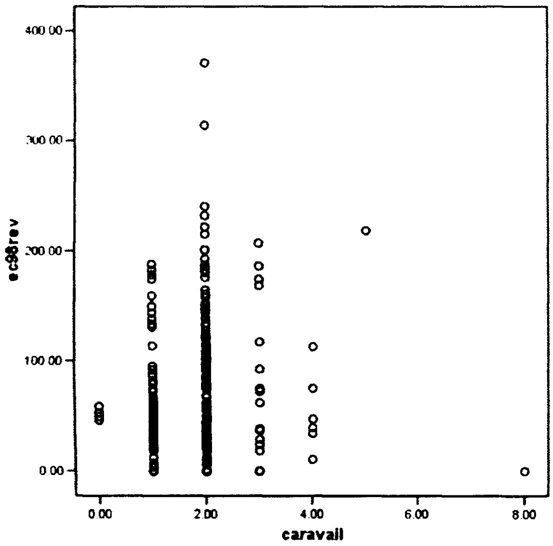
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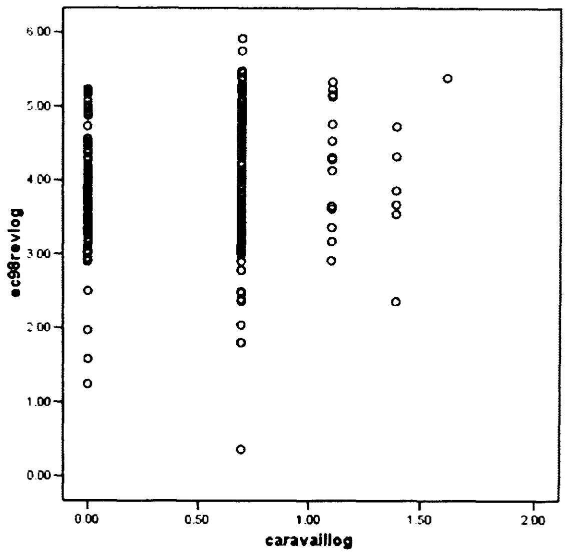
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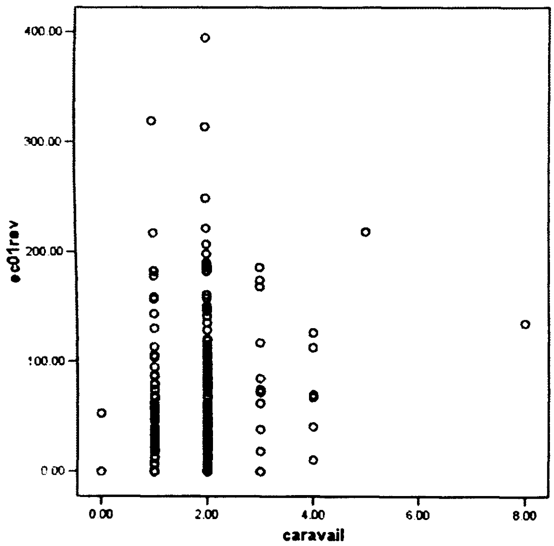
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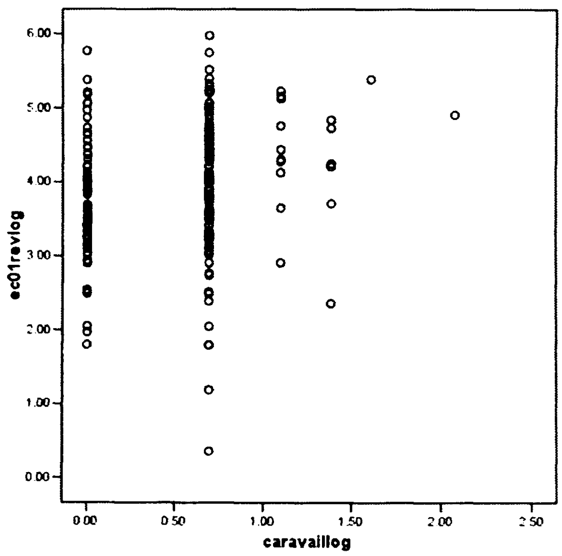
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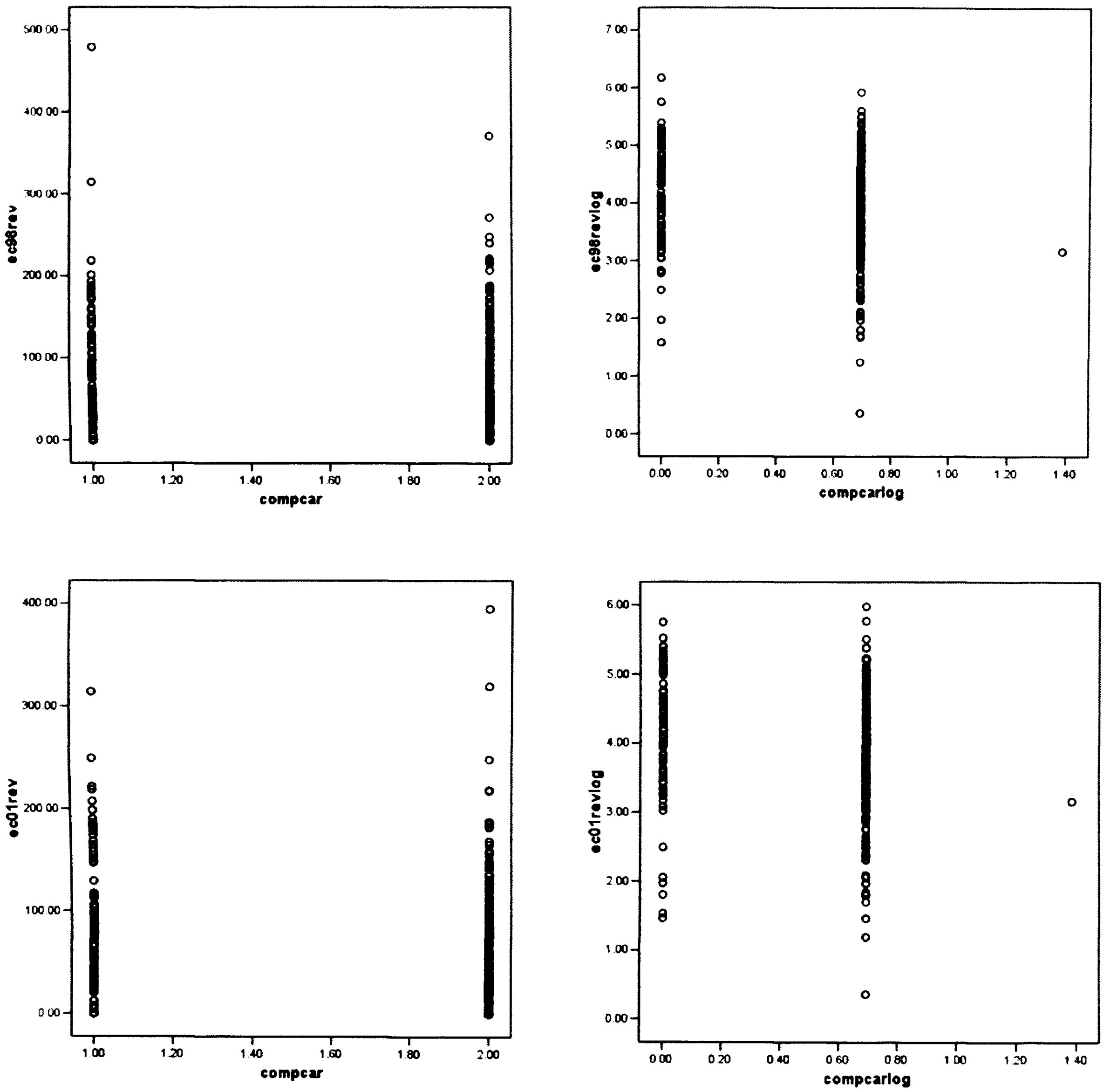
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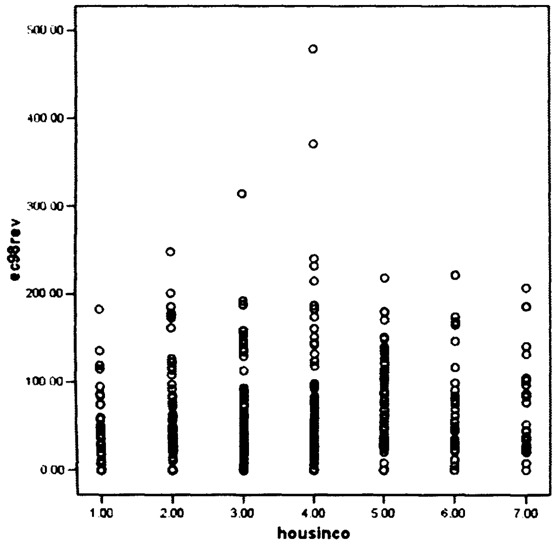
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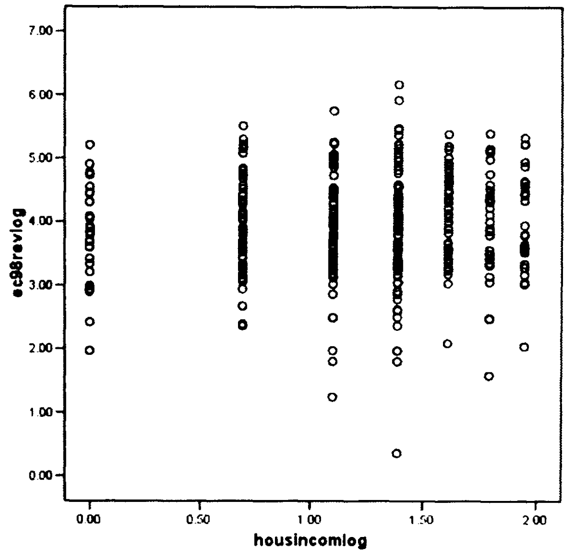
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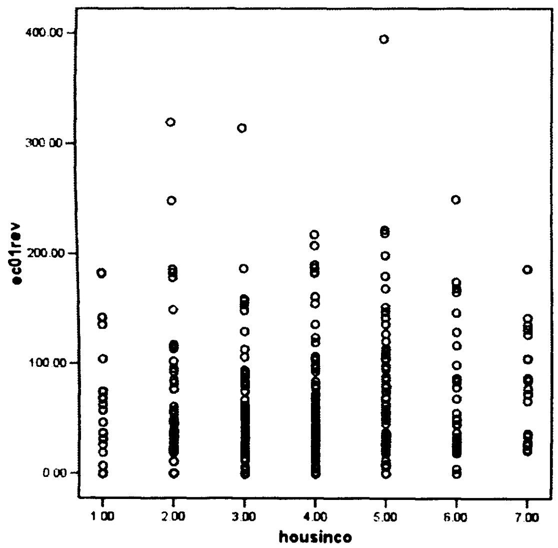
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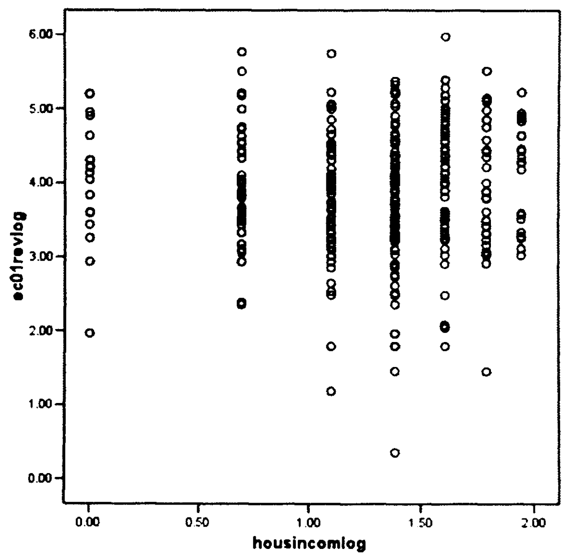
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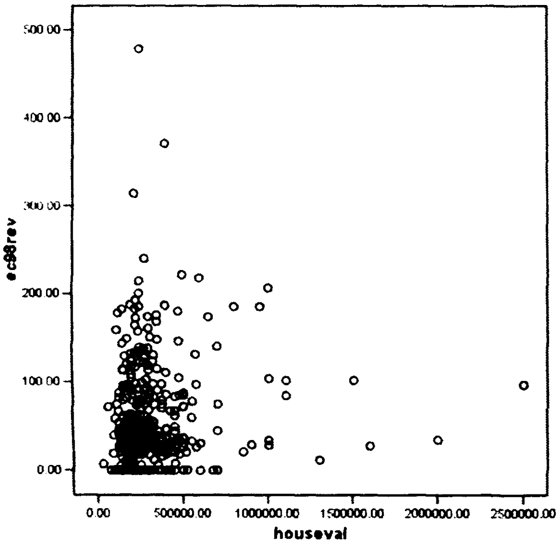
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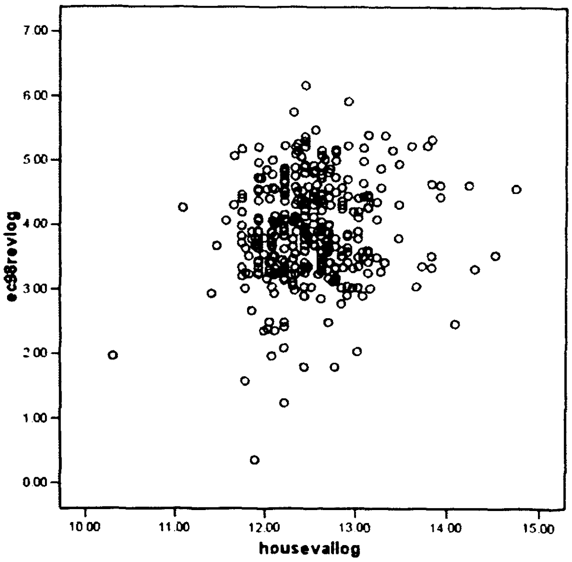
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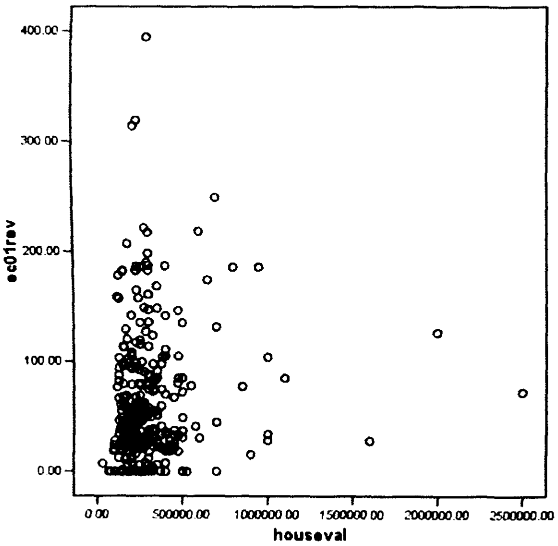
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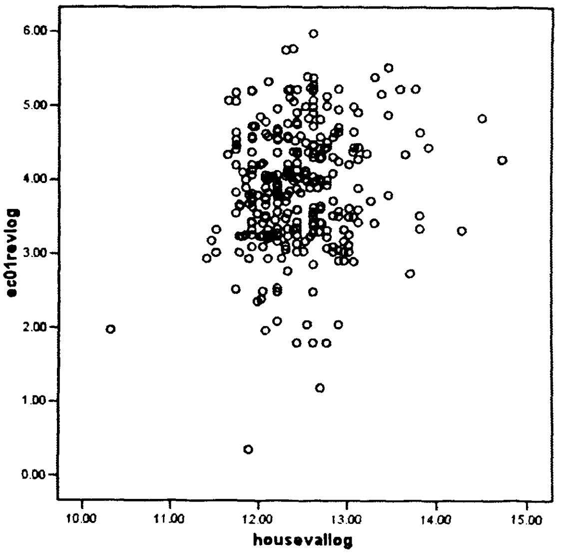
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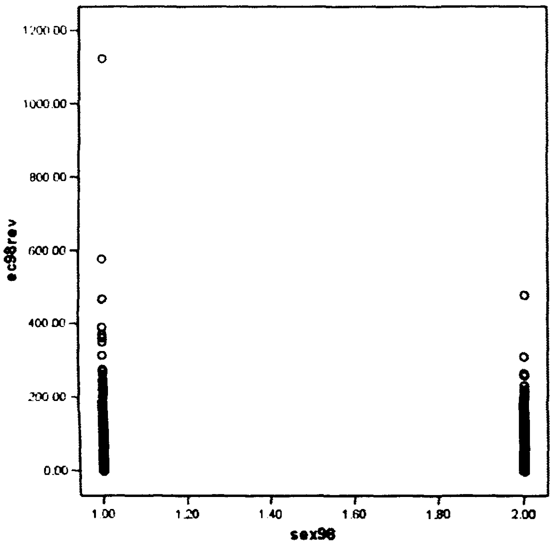
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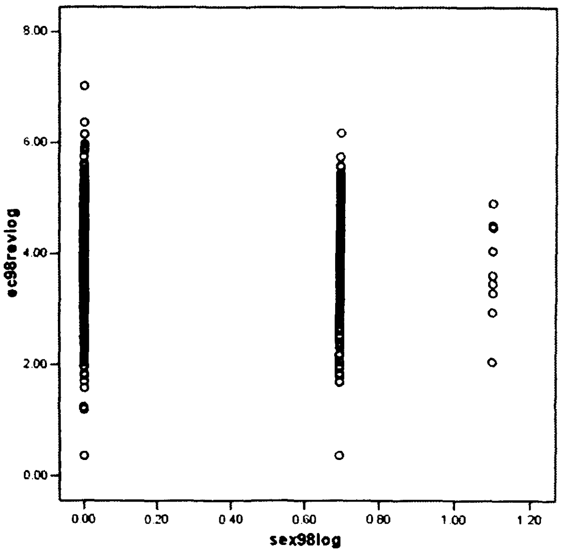
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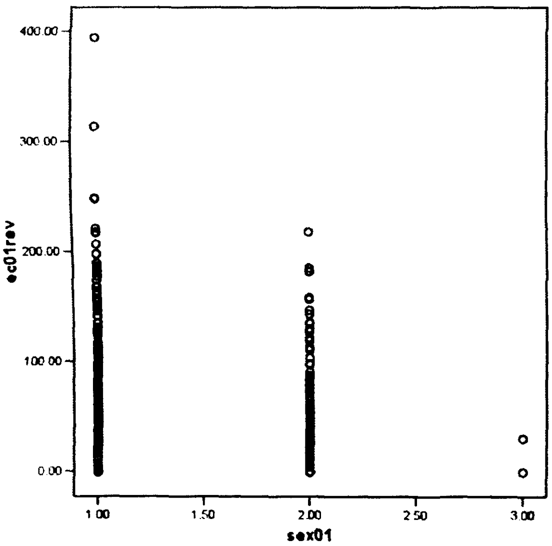
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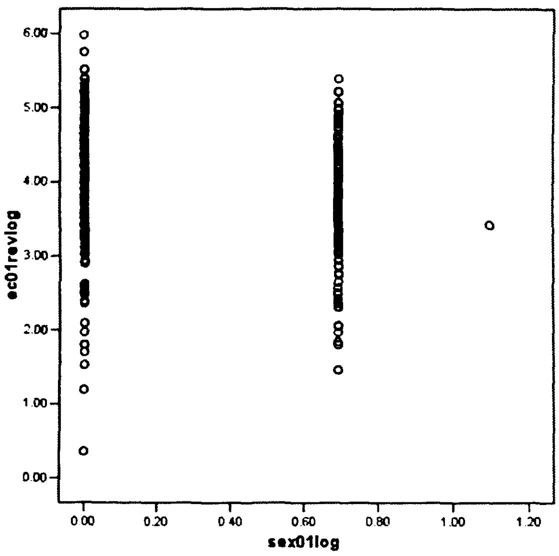
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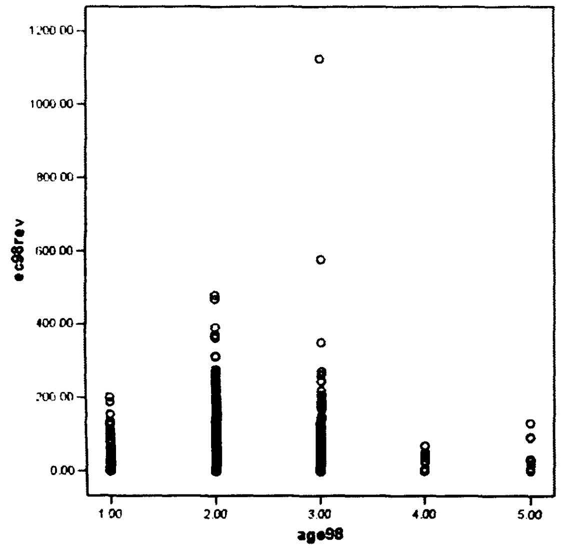
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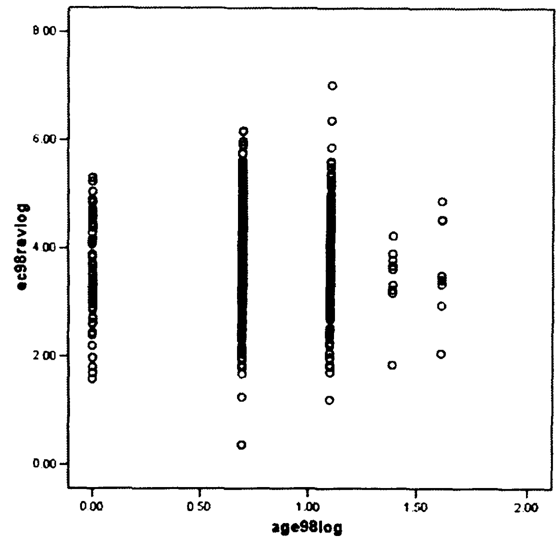
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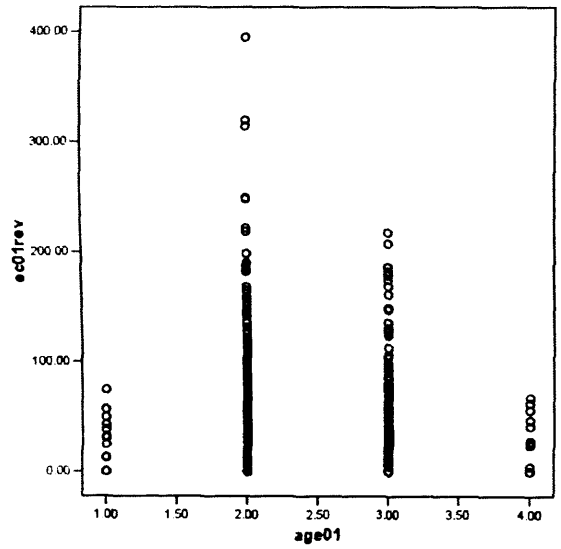
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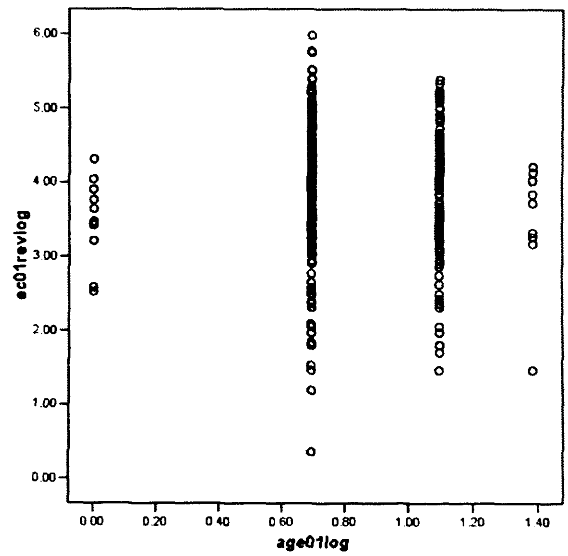
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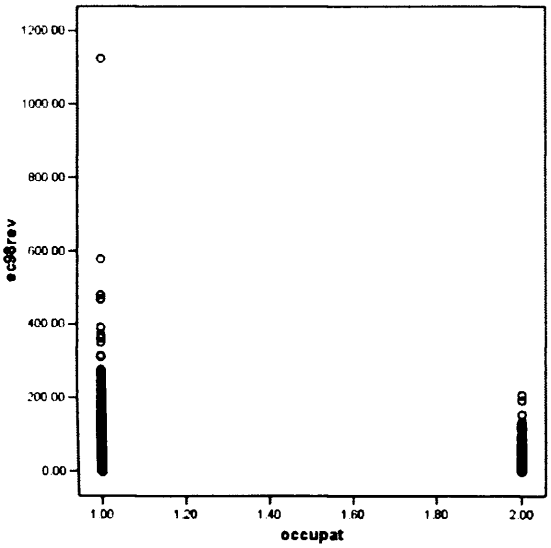
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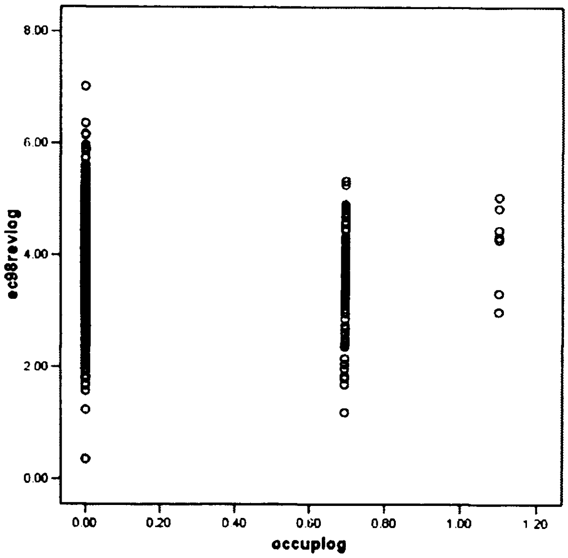
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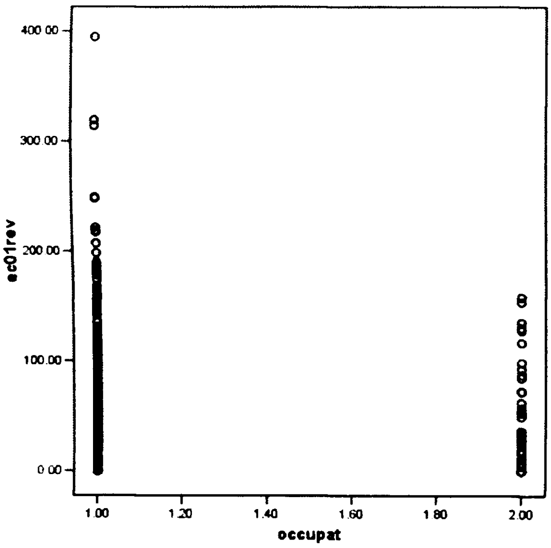
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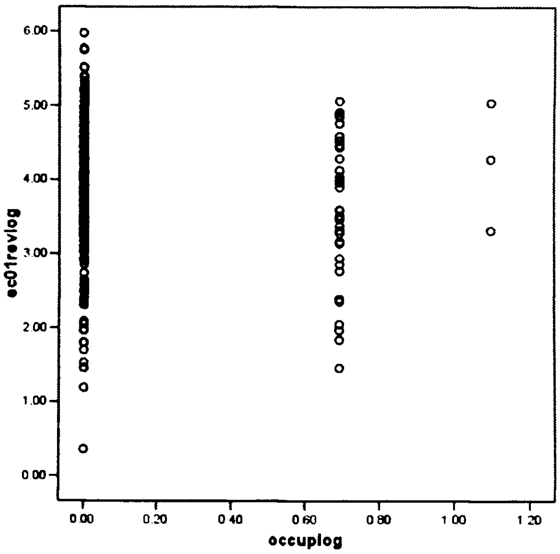
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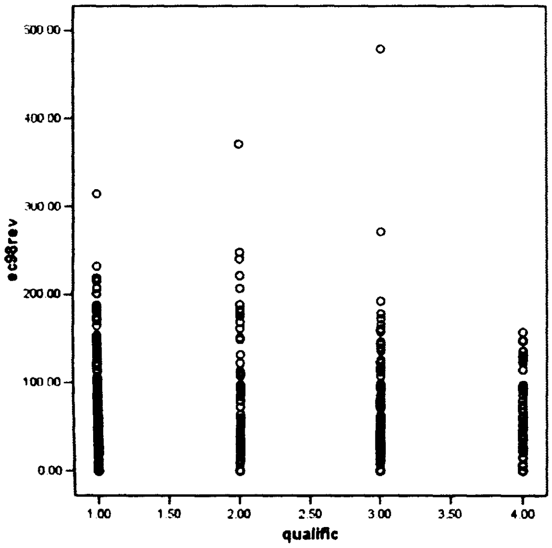
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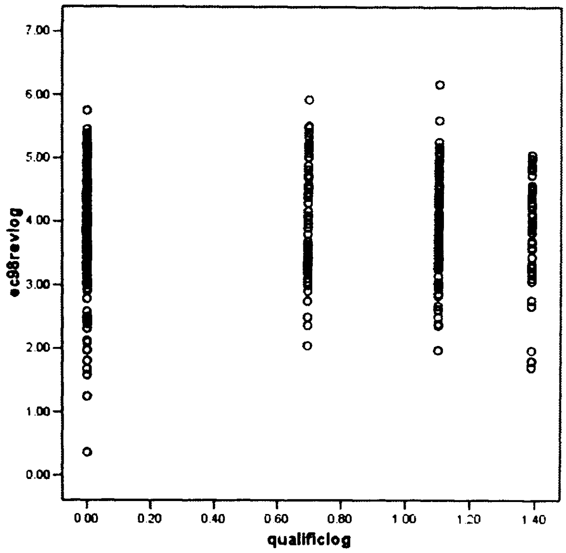
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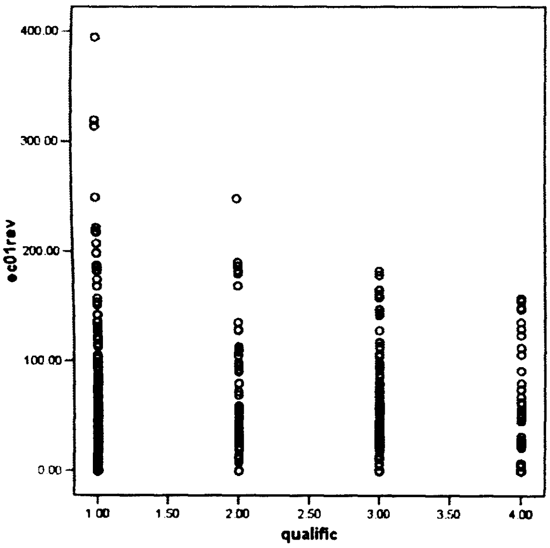
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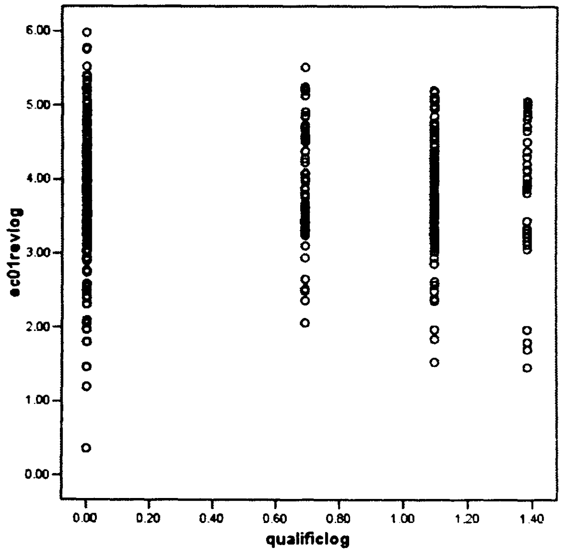
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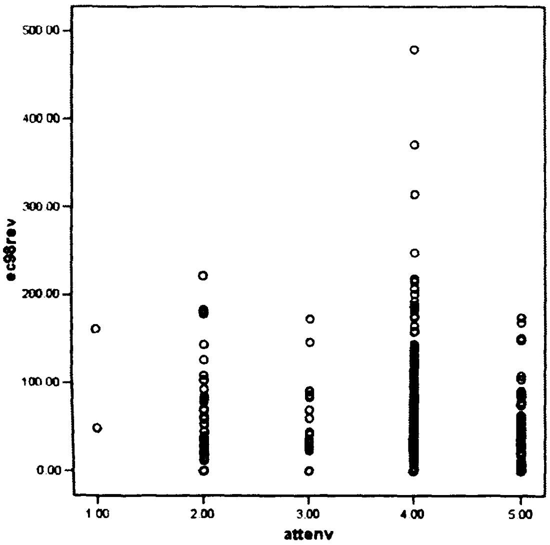
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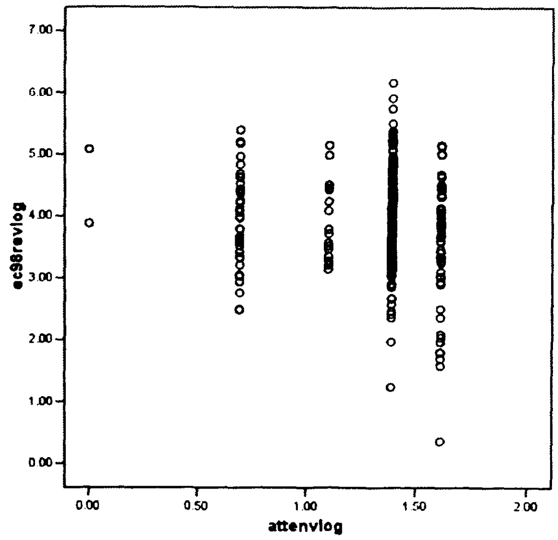
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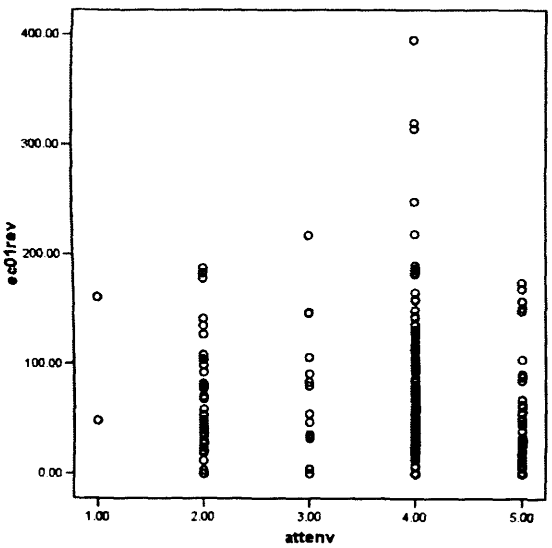
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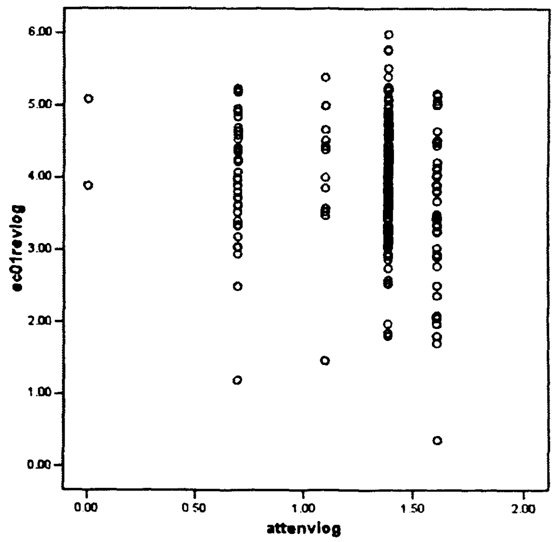
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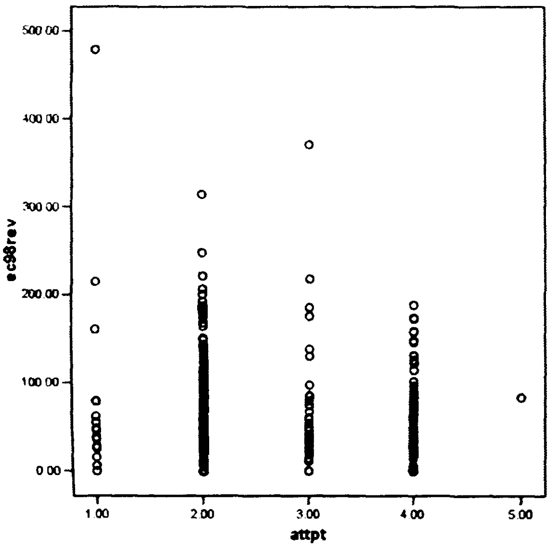
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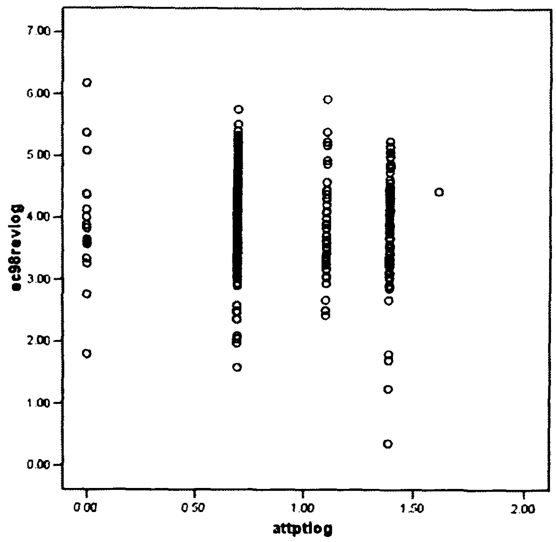
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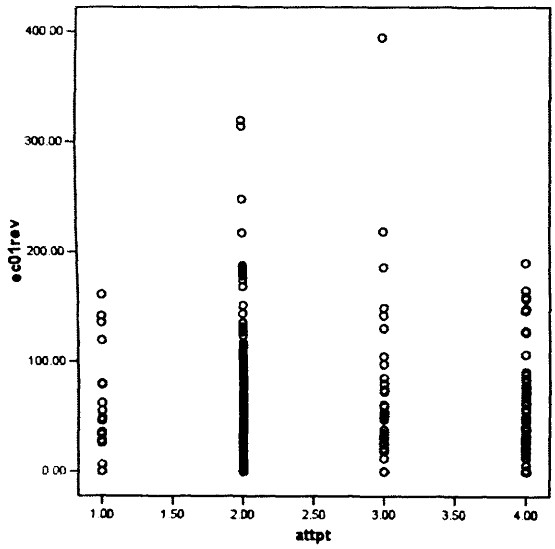
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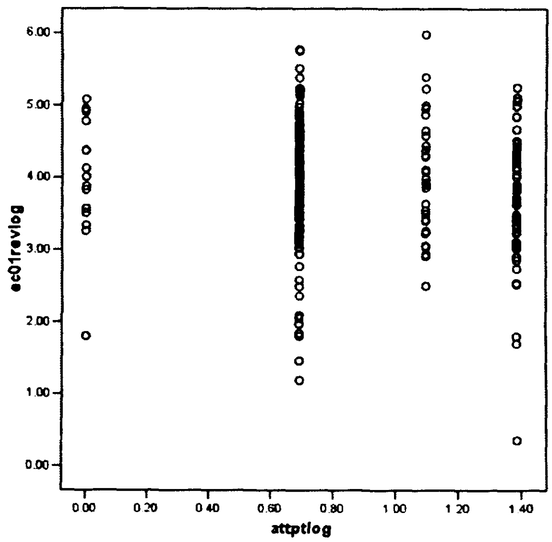
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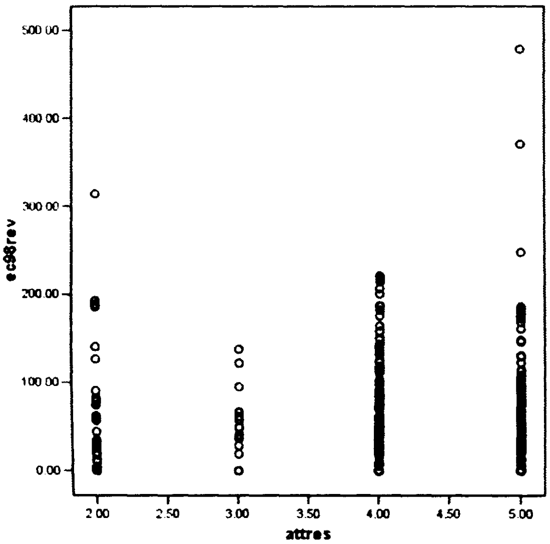
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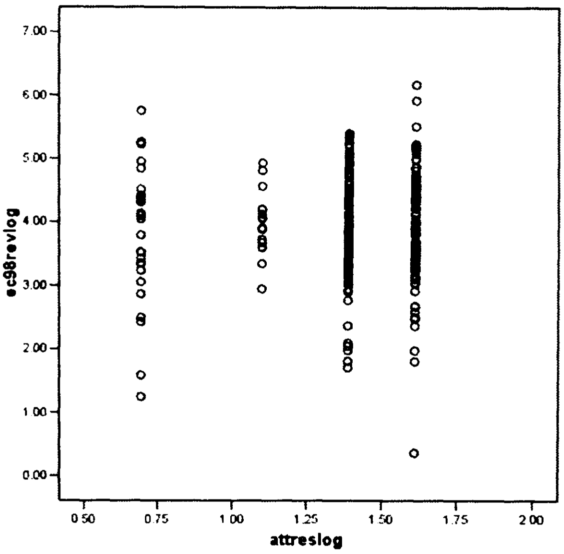
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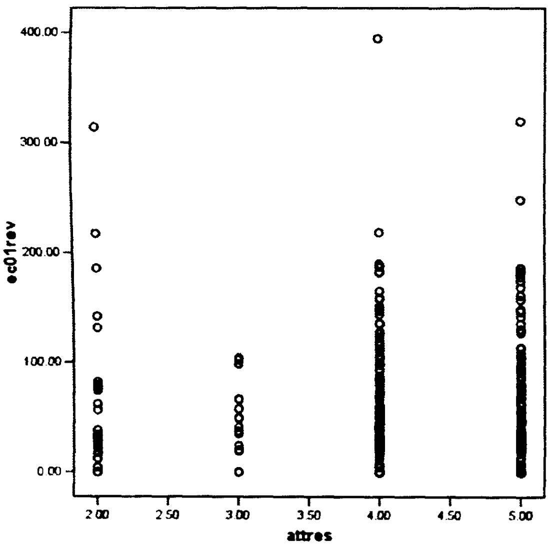
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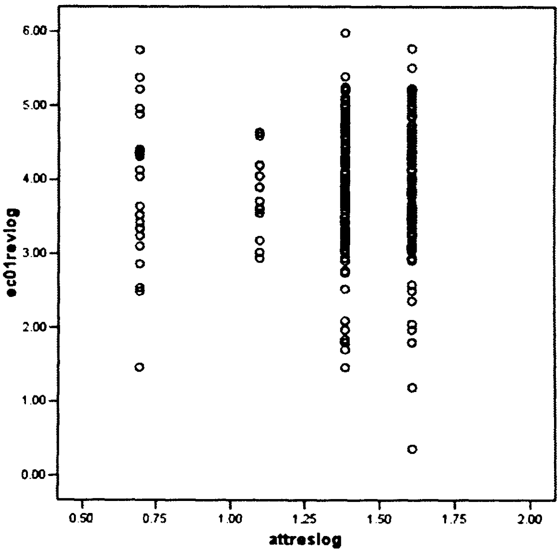
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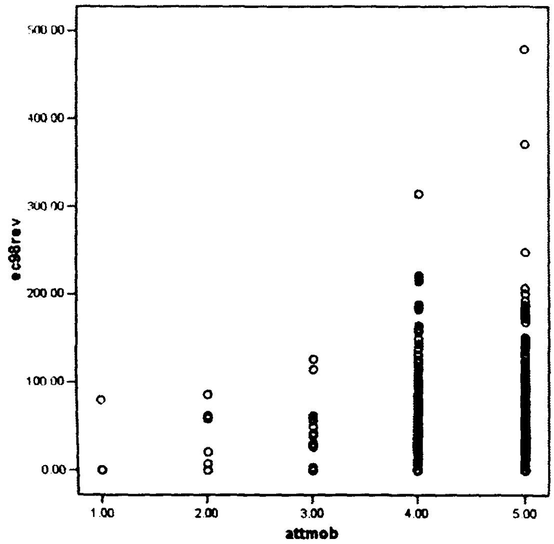
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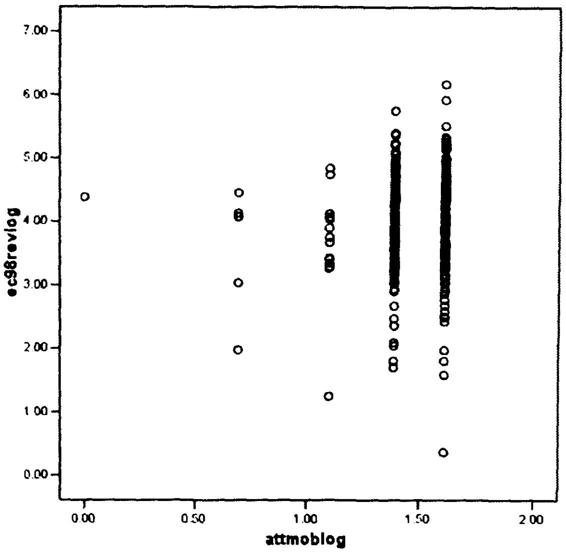
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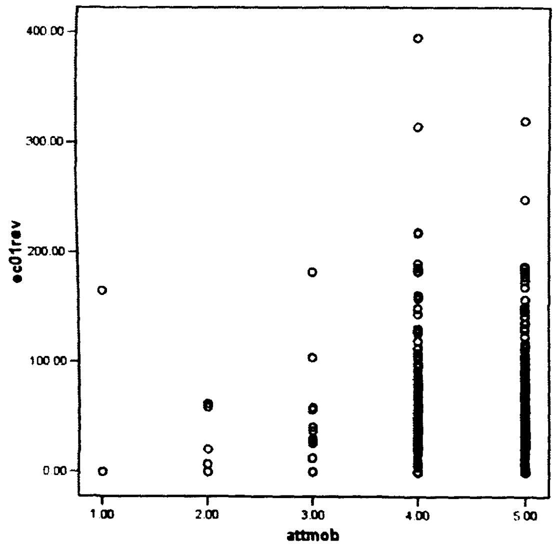
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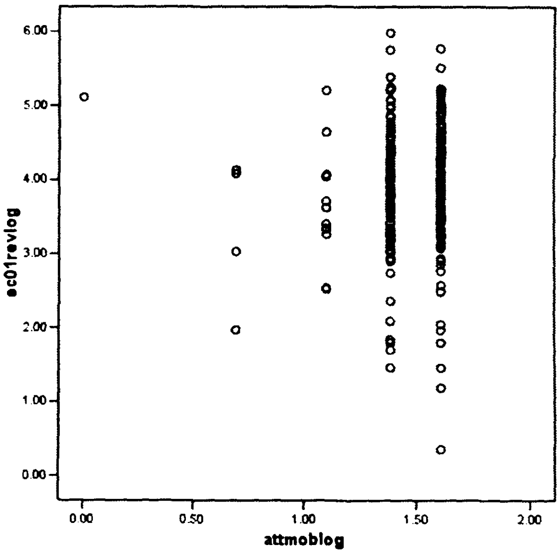
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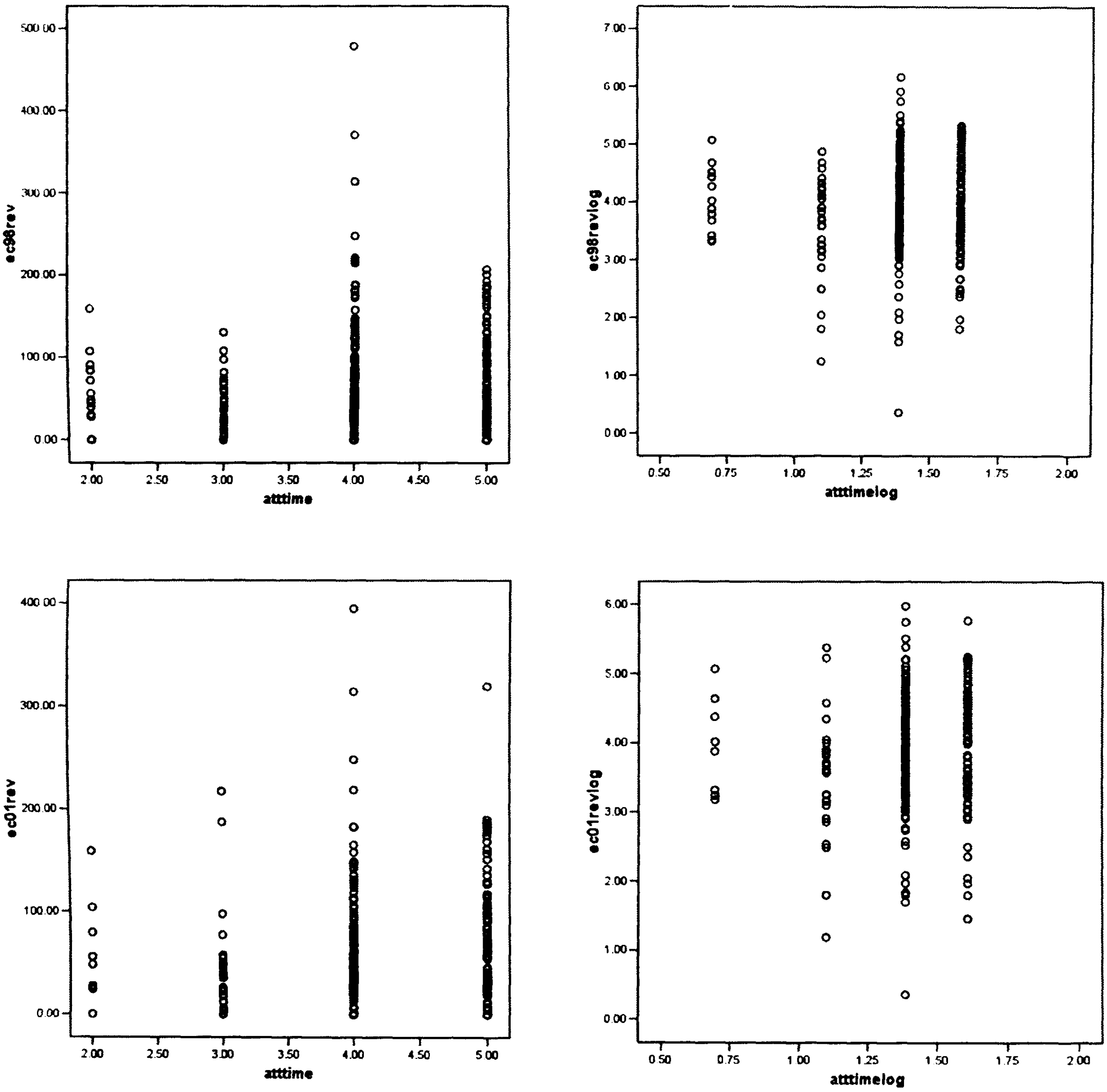
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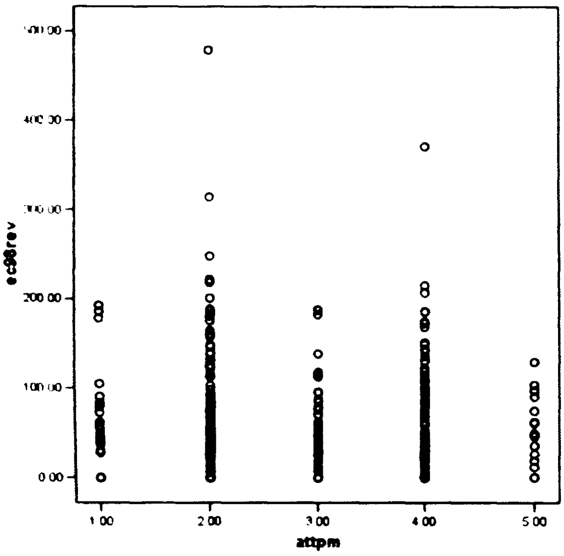
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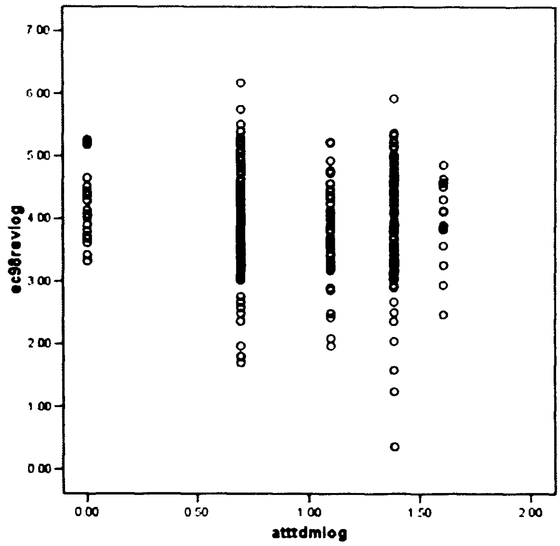
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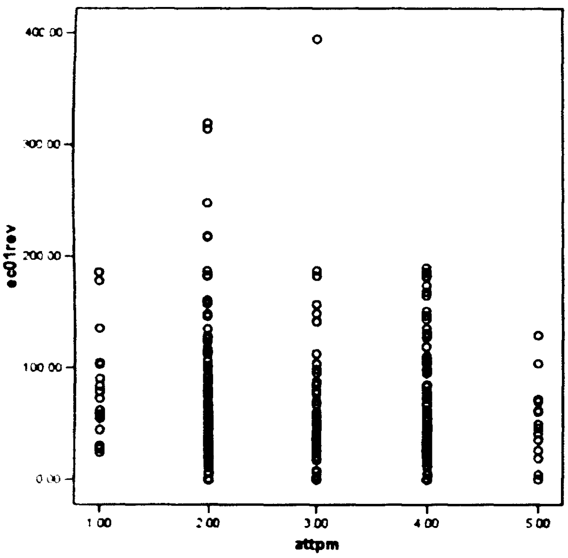
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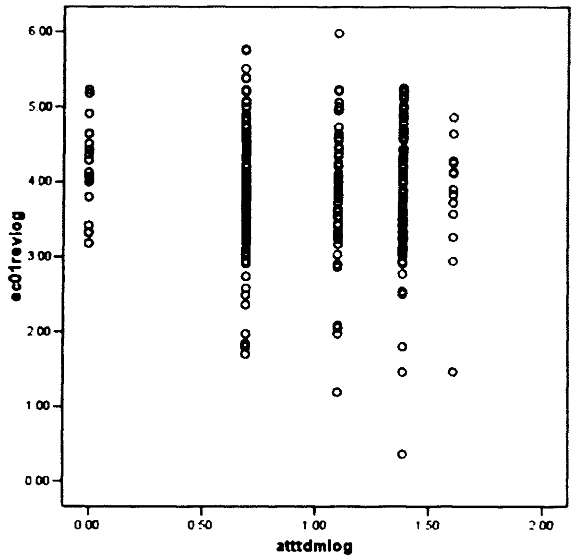
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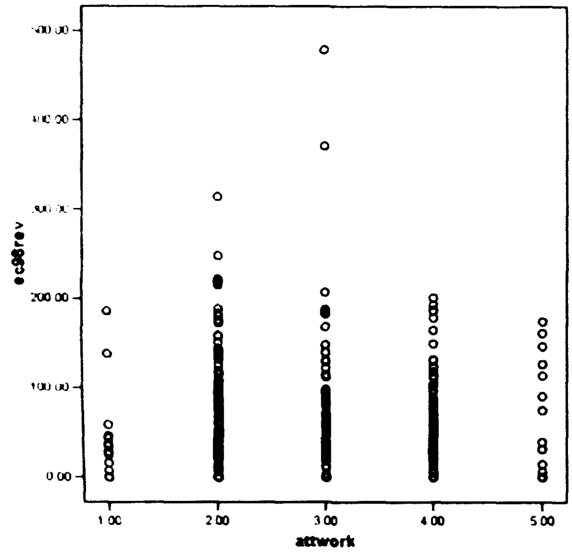
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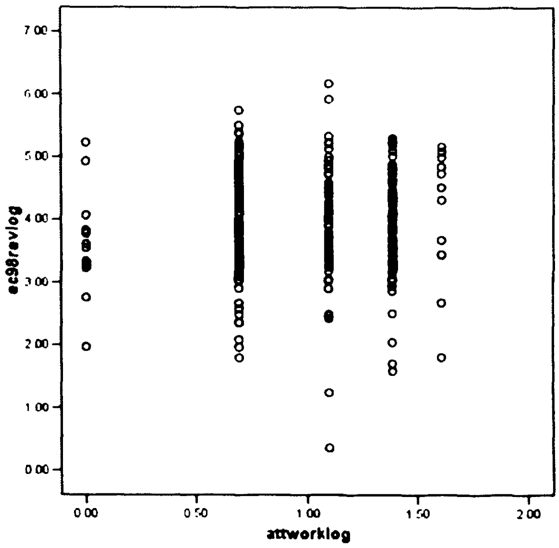
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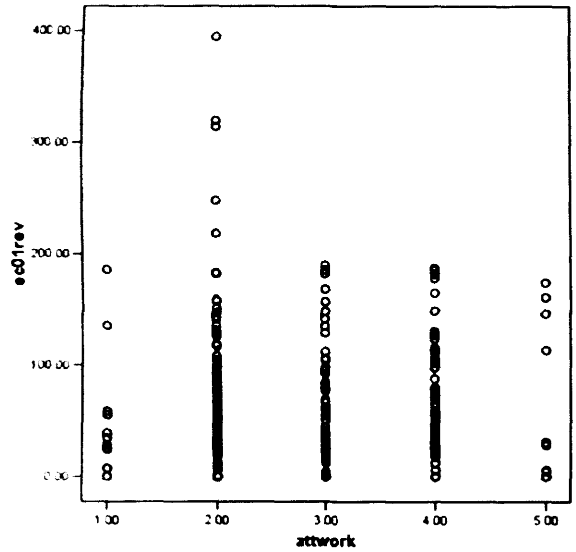
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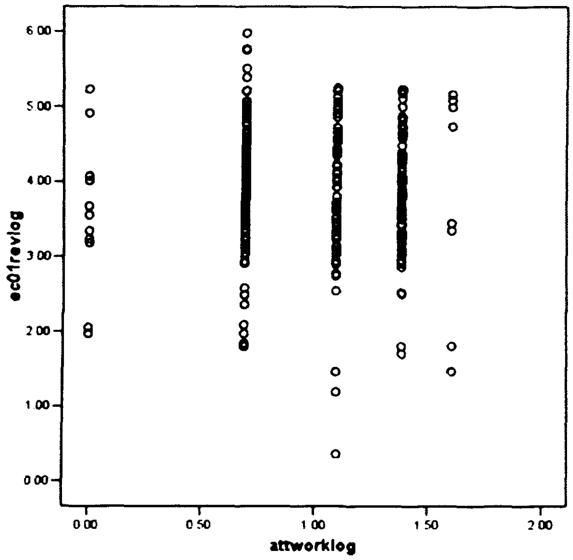
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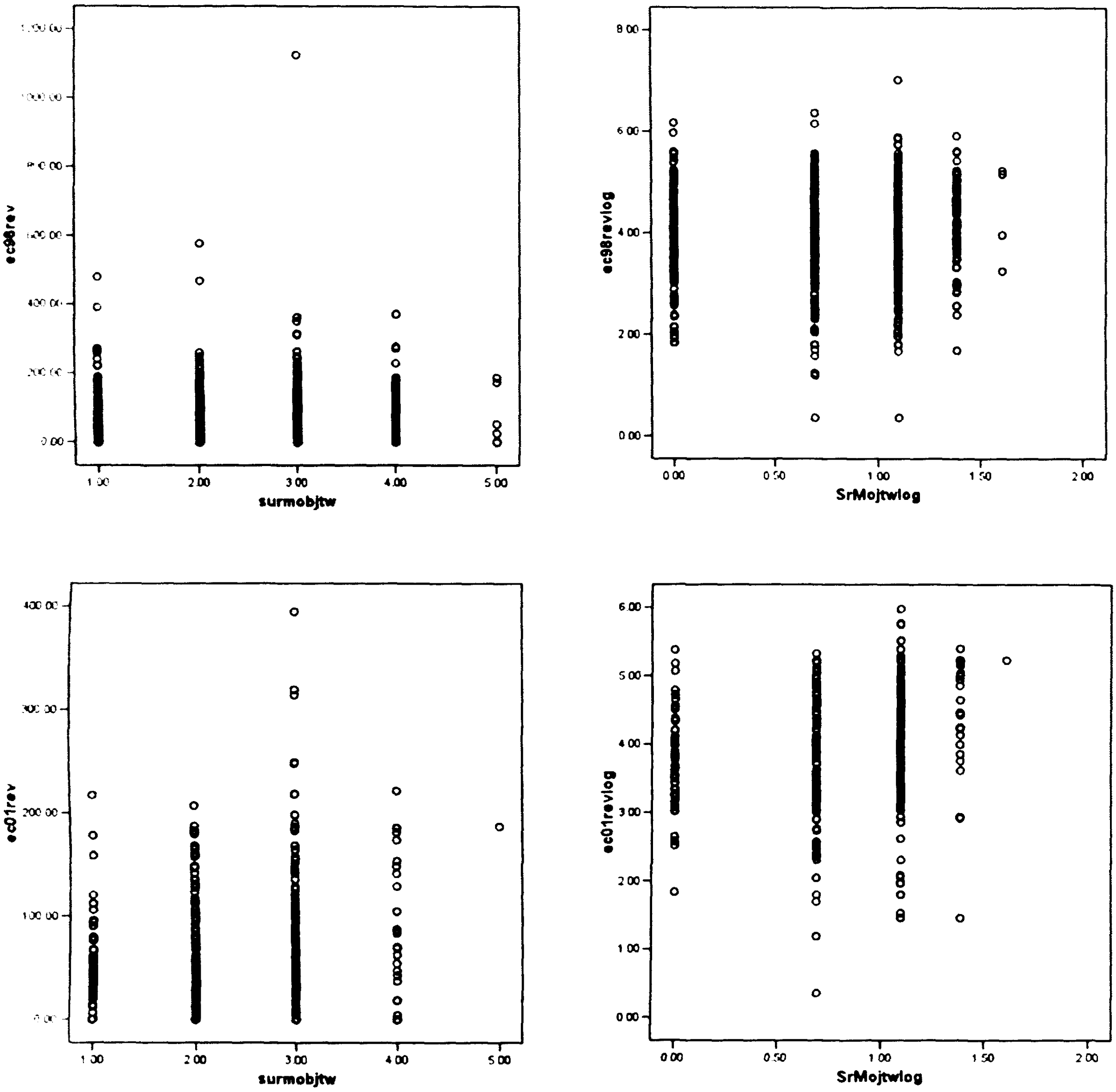
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4C. Linear Regression Outputs

Enter/stepwise/backward linear regression:

Stepwise multiple regression, sometimes also called statistical regression, is a way of computing linear regression in stages. In stage one, the independent variable best correlated with the dependent is included in the equation. In the second stage, the remaining independent with the highest partial correlation with the dependent, controlling for the first independent, is entered. This process is repeated, at each stage partialling for previously-entered independents, until the addition of a remaining independent does not increase R-squared by a significant amount (or until all variables are entered, of course).

Alternatively, the process can work backward, starting with all variables and eliminating independents one at a time until the elimination of one makes a significant difference in R-squared. Or, most commonly the process can be carried out in the order of entry of the variables.

Continuous data is required for all (interval or ratio), although it is common to use ordinal data.

Standard SPSS outputs include:

The output table titled 'variables entered/removed' outlines the order in which the variables are included in the analysis.

The model summary gives information about R square change, showing the amount that each variable contributes to R square, the F test value of the change, and the associated level of statistical significance.

The ANOVA analysis of variance table provides the F ratio for the whole equation and the level of significance.

Annex 6
References

We have seen previously that the literature in the urban planning, land use and transport field is developing at an ever-increasing rate. A full reference list for this thesis follows. However, first, a number of *key texts and articles*, which have particularly helped to move thinking forward, are highlighted below. They are drawn from the land use and transport interaction literature and the wider urban planning/sustainability literature. There is, of course, much overlap between the issues, and indeed, integration of the disciplines is critical.

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The full reference list is shown below.

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Rh/2007.

New Household Occupiers Survey 1998

Please answer the questions either by writing the appropriate number in the boxes to the right or, where indicated, by writing on the line provided. Please do not write in the shaded boxes.

1. What type of home do you live in?

(for example, if you live in a semi-detached house please enter 2 in the box to the right)

Detached House	1	Detached Bungalow	4	Purpose-Built Flat	7
Semi-Detached House	2	Semi-Detached Bungalow	5	Converted Flat	8
Terraced House	3	Terraced Bungalow	6	Other (state in shaded box below)	9

2. How many bedrooms does your home have?
(please enter number of bedrooms in box to the right)

3. What type of tenure do you have?

Owner Occupied (with mortgage)	1	Rented from Housing Association or Council	4
Owner Occupied (owned outright)	2	Privately Rented	5
Shared Ownership (with housing association or council)	3	Provided by Employer or Business	6
		Other (please state)	7

4. What was your main reason for moving from your previous home?
(Please select one reason from the list below and write the number in the box)

Change in workplace (new job)	1	To live in a good environment	7	Retirement	12
Access to existing workplace	2	To buy or rent your first home	8	To be close to family/friends	13
Access to good road network	3	Price of your new home	9	Marriage/other relationship	14
Access to good public transport	4	Move to a bigger house	10	Relationship breakdown	15
To be close to shops/leisure	5	Move to a smaller house	11	Other (state on dotted line)	16
To be near to good schools	6				

5. What were your main reasons for choosing this particular location for your new home?
(Please select up to 3 reasons from the list above, in order of importance, and write the numbers in the box)

6. How many children aged 16 or under live in your house?
(if you have no children please put a zero in the box and go to question 7)

If children do live in your house, how old were they on 1 June 2001?
(please write age, in years, of each child in the boxes)

Child 1 Child 2 Child 3
Child 4 Child 5 Child 6

Please answer the following questions for each adult who usually lives in your house who is aged 17 or over. Include students who live away from home during term time. If there are more than four adults in your house then please provide information for each of them on a separate piece of paper (Please complete one column for each adult).

7. Are you?

		Yourself	2nd Adult	3rd Adult	4th Adult
Male	1				
Female	2				

8. Please state your age group:

		Yourself	2nd Adult	3rd Adult	4th Adult
17-24	1				
25-44	2				
45-retirement age	3				
Over retirement age	4				

9. Are you:

		Yourself	2nd Adult	3rd Adult	4th Adult
Married/living with partner	1				
Single	2				
Widowed	3				
Divorced/separated	4				

10. Where did you live before moving into your new home?
(Please write the name of a town or village and county/London Borough or overseas country in the box provided)

Yourself	2nd Adult	3rd Adult	4th Adult

11. Was your previous home?

		Yourself	2nd Adult	3rd Adult	4th Adult
Owned (with mortgage singly or with others)	1				
Owned (outright)	2				
Shared Ownership (with housing association or council)	3				
Rented from housing Association or Council	4				
Privately rented	5				
Provided by employer or business	6				
Shared with Parents or Relatives	7				
Other (please state)	8				

12. How would you describe your present occupation?

		Yourself	2nd Adult	3rd Adult	4th Adult
Employed: full-time (30 hours or more per week)	1				
Employed: part-time (under 30 hours per week)	2				
Self employed	3				
Unemployed	4				
Looking after home or family	5				
Retired	6				

Student (full-time)	7				
Other (please state)	8				

(Please complete the rest of the questions for those adults who are currently employed or self employed)

13. Where do you now work?
(Please write the name of a town or village and county/London Borough or overseas country in the box below)

Yourself	2nd Adult	3rd Adult	4th Adult

14. If you changed your workplace at or about the time you moved, where did you work BEFORE?
(Please write the name of a town or village and county/London Borough or overseas country - showing where you worked before - in the box below)

Yourself	2nd Adult	3rd Adult	4th Adult

15. What is your present usual means of transport to work?
(If you use more than one means of transport then please give the means you use for the longest part, by distance)

		Yourself	2nd Adult	3rd Adult	4th Adult
Work mainly at home	1				
Car - driver	2				
Car - passenger	3				
Train or Underground	4				
Bus	5				
On foot	6				
Bicycle	7				
Other (please state)	8				

Thank you for your help

Please return your questionnaire in the pre-paid envelope to:
Environment, Surrey County Council, County Hall, Kingston upon Thames, Surrey, KT1 2DY

Re-Survey of the Occupiers of New Houses in Surrey

Please answer the questions by writing the appropriate answer or number in the shaded box provided. The survey should only take 5 minutes to fill in, so please persevere! Your answers will be extremely useful to our research.

1. What date did you move into this house?
(Please enter the year and month)

Year	
Month	

Household Characteristics

2. What type of tenure do you have?
(For example, if you own your own house please enter 1 in the box to the right)

Owner occupier (with mortgage)	1	Rented from housing association or council	4
Owner occupier (owned outright)	2	Privately rented	5
Shared ownership (with housing association or council)	3	Provided by employer or business	6
		Other (state in shaded box below)	7

(If you are an owner-occupier, please go to question 3, if not go to question 4)

3. What is your approximate house value?
(Answer to the nearest £25,000)

£

4. How many children aged 16 or under live in your house?
(If you have no children please put a zero in the box to the right)

If children do live in your house, HOW OLD were they on 1st June 2001? *(please write age, in years, of each child in the boxes)*	Child 1		Child 2		Child 3	
	Child 4		Child 5		Child 6	

5. How many cars or vans are normally available for use by you or members of your household?
(Please enter number of cars in box to the right)

SURREY COUNTY COUNCIL

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Individual Characteristics

Please answer the following questions for each adult who usually lives in your house who is ***aged 17 or over****. Include students who live away from home during term time. If there are more than four adults in your house then please provide information for each of them on a separate piece of paper (Please place a tick in the correct box for each adult).*

6. Are you?

	Yourself	2nd Adult	3rd Adult	4th Adult
Male				
Female				

7. Please state your age group:

	Yourself	2nd Adult	3rd Adult	4th Adult
17-24				
25-44				
45-retirement age				
Over retirement age				

8. Are you:

	Yourself	2nd Adult	3rd Adult	4th Adult
Married/living with partner				
Single				
Widowed				
Divorced/separated				

9. Where did you live before moving into your new home?
(Please write the name of a town or village and county/London Borough or overseas country – and postcode if you know it - in the box provided)

Yourself	2nd Adult	3rd Adult	4th Adult

10. How would you describe your present employment?

	Yourself	2nd Adult	3rd Adult	4th Adult
Employed: full-time (30 hours or more per week)				
Employed: part-time (under 30 hours per week)				
Self employed				
Unemployed				
Looking after home or family				
Retired				
Student (full-time)				
Other (please state)				

11. What is your total annual household gross income?

Less than £19,999	
£20,000-£34,999	
£35,000-£49,999	
£50,000-£69,999	
£70,000-£99,999	
£100,000-£149,999	
More than £150,000	

12. What is your highest qualification?

	Yourself	2nd Adult	3rd Adult	4th Adult
Degree or higher				
A level				
O level/GCSE/CSE				
None				
Other (please state)				

Workplace and Travel to Work

Please complete questions 13 to 18 for those adults who are currently employed or self employed.

13. Where did you work when you first moved into this house?
(Please write the name of a town or village and county/London Borough or overseas country – and postcode if you know it - in the box below)

Yourself	2nd Adult	3rd Adult	4th Adult

14. Where do you now work?
(Only complete this question if the answer is different to that in question 14)

Yourself	2nd Adult	3rd Adult	4th Adult

15. What is the full title of your main job?
(For example; primary school teacher, state registered nurse, car mechanic, benefits assistant, company director)

Yourself	2nd Adult	3rd Adult	4th Adult

16. What is the business of your employer at the place where you work?
(For example; making shoes, repairing cars, secondary education, clothing retail, doctors surgery)

Yourself	2nd Adult	3rd Adult	4th Adult

SURREY COUNTY COUNCIL

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Faculty of the Built Environment

17. What is your present usual means of transport to work?
(If you use more than one means of transport then please give the means you use for the longest part, by distance)

	Yourself	2nd Adult	3rd Adult	4th Adult
Work mainly at home				
Car - driver				
Car - passenger				
Train or Underground				
Bus				
On foot				
Bicycle				
Other (please state)				

18. Do you have a company car?

	Yourself	2nd Adult	3rd Adult	4th Adult
Yes				
No				

Attitudes to Home and Travel

Please answer the following questions yourself – GIVING YOUR OWN VIEW (not that of other members of the household) – and write the appropriate number in the shaded boxes to the right. If other members of the household have different views, feel free to indicate these on a separate piece of a paper.

19. How satisfied are you with your AREA of residence?
(Think in terms of the local environment, facilities and accessibility)

Very satisfied	1	
Satisfied	2	
Dissatisfied	3	
Very dissatisfied	4	
Other (please state)	5	

20. Which location would you PREFER to live in (in an ideal world)?
(Please choose one location)

City centre	1	
Redeveloped dockland area	2	
Inner urban area	3	
Major suburban centre	4	
Suburban area	5	
Rural village centre	6	
Remote rural area	7	
Other (please state)	8	

21. What type of home would you PREFER to live in (in an ideal world)?

Detached house	1	
Semi-detached house	2	
Terraced house	3	
Detached bungalow	4	
Semi-detached bungalow	5	
Terraced bungalow	6	
Purpose-built flat	7	
Converted flat	8	
Other (please state)	9	

22. Open space: which would you prefer?

Your own garden	1
Shared garden with access by immediate neighbours only	2
No garden but easy access to public open space	3
No open space	4
Other (please state)	5

23. Car parking: which would you prefer?

Parking in secure garage	1
Parking in off-road parking space	2
Parking on road	3

24. Attitudes to the environment and travel
(Please score the following statements according to the scale below)

Strongly agree	1
Agree	2
Neither agree nor disagree	3
Disagree	4
Strongly disagree	5
Don't know	6

Environment	*Score (1-6)*
Environmental protection costs too much	
Environmental protection is good for the Surrey economy	
Environmentalism hurts small businesses	
People and jobs are more important than the environment	
Strict pollution controls should be introduced and enforced	
Petrol prices should be raised to reduce congestion and air pollution	
Vehicle emissions increase the need for health care	
Using taxes to pay for public transport is a good investment	
We should provide incentives to people who use electric vehicles	
Whoever causes environmental damage should repair the damage	

Public Transport	
Buses and trains are pleasant to travel in	
I can read and do other things when I use public transport	
Public transport is unreliable	
Car sharing saves money	
I am not comfortable car sharing with strangers	
I like someone else to do the driving	
Too many people drive alone	
It costs more to use public transport than to drive a car	
I use public transport when I cannot afford to drive by car	

Residence	
I need to have space between me and my neighbours	
I would only live in a block of flats as a last resort	
It's important for children to have a large back garden for playing	
High density residential development should be encouraged	
Having shops and services within walking distance is important	
Too much green belt and agricultural land is consumed by new housing	

Mobility

Driving allows me to get more done	
Driving allows me more freedom	
I would rather drive an electric vehicle than give up driving	

Time pressure

Getting stuck in traffic doesn't bother me too much	
I would like to have more time for leisure	
I feel that I am wasting time when I have to wait	
Traffic congestion will take care of itself because people will adjust	

Traffic management

I would be willing to pay a toll to drive on an uncongested road	
I would be willing to pay to park at work if it meant there would be less congestion	
More lanes should be set aside for buses and car sharing	
We need to build more roads to help reduce congestion	

Work

I like to spend most of my time working	
When busy at work, I get more done by cutting back on personal time	
I would be willing to give up a day's pay to get a day off work	

25. Transport Policy Options and Behavioural Change
(From the list below, please rank: the top 10 most effective ways of ENCOURAGING YOU to drive less frequently to work. Please provide a score for only 10 of the measures and leave the other spaces blank)

		Reducing YOUR travel Rank 1-10
Improvements to footways	1	
Increased provision of cycle paths and more secure cycle parking	2	
Help to purchase cycles	3	
Showers/lockers at work	4	
More frequent bus services and bus more service routes	5	
Later and/or earlier bus running times	6	
More bus priority lanes	7	
Cheaper bus fares	8	
More comfortable buses	9	
Advanced knowledge at bus stops (e.g. real-time countdown service information)	10	
More frequent train services	11	
Later and/or earlier train running times	12	
Cheaper train fares	13	
More comfortable trains	14	
More train stations	15	
Integrated bus and train times	16	
Integrated bus and train fares (e.g. a common ticket for both bus and train)	17	
Providing school bus services for children	18	
Allowing people to work at home more often	19	
More car parking at stations	20	
Car sharing schemes	21	
Park and ride services	22	

More expensive car parking in the main towns in Surrey	23	
More expensive car parking at work	24	
More expensive petrol prices	25	
Charging for driving into the main towns in Surrey	26	
Charging for driving on the main roads (e.g. the motorways) in Surrey	27	
Increased road maintenance	28	
Other measures (please state)	29	

Please give us any further comments you may have on this survey, or the issues covered in this survey.

Once again, many thanks for your help – your answers will help us to help improve the environment and quality of life in Surrey.

Do you want to be entered in the prize draw for £100?

Yes	
No	

We may wish to follow up some of these surveys with a telephone interview. Would you be willing to help? – If so, please provide your name and telephone number in the space below:

Name:	
Tel:	

Please return your questionnaire *in the pre-paid envelope to:*
Environment, Surrey County Council, County Hall, Kingston upon Thames, Surrey, KT1 2BR